



Rockwell International

Space Division

(NASA-CR-151814) QUICK LOOK TEST REPORT: N78-29141
MPT STATIC FIRING NO. 2 TEST MPT-S2
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FOREWORD

This report has been prepared and published by Rockwell International, Space Division, as STS Integration Contractor in accordance with Contract NAS9-14000. The contents of this document are based on inputs provided by NASA-MSFC, JSC, KSC, Martin-Marietta Company, and Rockwell International-Rocketdyne and Space Divisions.



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SECTION 1.0 INTRODUCTION AND SUMMARY

The second static firing test (Test Number MPT-S2-001) of the Main Propulsion Test Article (MPTA) was successfully conducted at the National Space Technology Laboratories (NSTL), Bay St. Louis, Mississippi, on 19 May 1978. The major test objective was to fire the three-engine cluster at 70 percent power level for a nominal 15 seconds to evaluate the integrated performance of the Main Propulsion System.

The countdown proceeded in a relatively good fashion. There were only three significant holds that were encountered. The first was a facility LH2 leak that developed in a line joint. The second was caused by a need to reset all of the RASCOS cutoff devices. The third was the failure to ignite one of the free hydrogen burnoff burners.

Engine ignition occurred at approximately 1403 with the planned mainstage duration achieved for all three engines. The total firing time for all three engines was as follows:

Engine #1	-	19.7 seconds
Engine #2	-	20.85 seconds
Engine #3	-	20.73 seconds

Operation of all systems was as expected with the exception of the recirculation pumps. The pumps were started while the propellant loading was in fast fill, but they cavitated and lost head at the termination of fast fill. The pumps were subsequently restarted after pressurizing the tank and draining back propellant to get good quality. This problem was primarily attributed to excessive back pressure in the facility vent system which is being corrected.

Post test inspection of the engines revealed some discoloration on the inside of the thrust chamber and distorted drain lines for Engine #2 (SN 2002). This was attributed to a post cut-off engine main fuel valve leakage. The valve has since been replaced.

Post test inspection of the ET pressurization diffusers revealed evidence of damage, which required their replacement.

Primary test objectives for this firing and results are as follows:

ObjectiveResults

Start, maintain 70% power level for 15 seconds, and shutdown the three MPS engines.

Satisfactorily accomplished.

Verify capability of integrated propellant feed system to satisfy SSME interface requirements throughout fill, engine conditioning, and engine firing, including start and cut-off transients.

Satisfactorily accomplished.

Evaluate LH2 recirculation and high-point bleed system performance.

Partially accomplished (adverse effects of LH2 replenish procedure prevented positive verification).

Evaluate LO2 and LH2 tank pre-pressurization and engine-run pressurization.

Satisfactorily accomplished.

Determine ignition overpressures resulting from start sequence.

Not completed due to questionable instrumentation data.

Evaluate SSME stub nozzle side-load effects in flight system installation.

Satisfactorily accomplished.

Verify hydraulic and TVC system performance in maintaining engine positions and SSME interface pressures during start and shutdown transients.

Satisfactorily accomplished.

Evaluate modified propellant loading procedure to maintain positive ET ullage pressure.

Satisfactorily accomplished.

Evaluate structural-dynamic loads versus predicted levels.

Satisfactorily accomplished, with available instrumentation.

Evaluate radiant heating environment.

Satisfactorily accomplished.

Verify functional performance of all test article, GSE, and facility systems to support increased power level firings.

Satisfactorily accomplished.



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Several actions were generated as a result of the firing. These actions are listed in Table 1.0-1.

Based on the analysis of data, it was concluded that the primary objectives of Static Firing 2 had been sufficiently satisfied to permit proceeding to the next planned firing.



TABLE 1.0-1

NSTL ACTION LIST - STATIC FIRING NO. 2
(Sheet 1 of 2)

Item No.	Action Required
SF 2-1	Conduct a review of the specification requirements applied to gas sampling on the MPTA Facility. Insure that specifications are realistic, achievable, and clear. Make recommendations for changes to II's and procedures.
SF 2-2	Re-examine high point bleed system to determine cause and solution to loss of LH2 recirculation pumps during tanking. One solution may be to route the high point bleed line directly into the 18-inch vent line instead of the four-inch line.
SF 2-3	Determine location of hydrogen leak in area of Engine No. 1 power head. Evaluate the need for a special test requirement at a higher pressure than normal.
SF 2-4	Determine the type of diffuser to be installed in LH2 tank which will be good through the next two static firings as a minimum and determine installation schedule.
SF 2-5	Review solenoid valves on facility with respect to recent failures and determine method of detection, preliminary checks that can be made to detect a potential failure.
SF 2-6	Fix the problem with PCV 469 failure in the auto mode. PE 469 has failed twice.
SF 2-7	Determine permanent fix to the problem of the crossed LOX vent valve actuation lines versus the switch actuation procedures and the light indications of the MTCE panel.
SF 2-8	Design and install final auxiliary helium bubbling system.



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TABLE 1.0-1

NSTL ACTION LIST - STATIC FIRING NO. 2
(Sheet 2 of 2)

Item No.	Action Required
SF 2-9	Re-evaluate the MPTA shutdown logic with respect to time delays and prepare advantages/disadvantages of having a master switch to shut all three engines down simultaneously. (1) Current time delays (2) Simultaneous shutdown
SF 2-10	Evaluate problem of SATS during gimbal versus pg. call-up.
SF 2-11	Investigate post shutdown fire and determine appropriate action.
SF 2-12	Review redline set-up procedures with particular attention to RASCO set-ups.
SF 2-13	Determine the need for another special gimbal/hydraulic test. If one is needed, devise the special test and submit a SAR to NSTL.
SF 2-14	Implement a closed loop system on data squawks.
SF 2-15	Implement a system for evacuating tank pressure transducers (Vacuum reference system).
SF 2-16	Prepare a standard to prevent cross-wiring. Include special polarity tests when changes are made.
SF 2-17	Incorporate changes to ATVC control systems to prevent one channel loss from causing shutdown.
SF 2-18	Insure that emergency procedures include consideration of the minimum 1.5 psi in the LOX tank.



2.0 MPTA Static Firing No. 2 Configuration

The MPTA configuration for static firing number two was the same as static firing number one, with the additional modifications to each element as listed below:

ORBITER

MCR 4969	MEC Redundant Power
MCR 5377	Preburner Purge Time Delay
MCR 5217	SSME Strain Gages
MCR 3604	LH2 Recirculation Valve

EXTERNAL TANK

ECPB00632Z	Relocate Helium Injection Orifice
ECPB00645A	Auxiliary Helium Injection Line Support
ECPB00716	MPTA Nose Spike Removal
ECPB00765	Hardwire Existing Strain Gages - MPTA
ECPB00792	Revise Range of Delta-P Transducer Across LOX Screen
ECPB00795	Installation of Orifice in GO2 Vent System

SSME

ECP072	POGO DFI (Partial)
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3.0 Test Operations

3.1 Countdown and Test Sequence

The countdown for Static Firing 2 was initiated at 075747 on 19 May 1978 with the start of Sequence S1.

LO2 and LH2 systems' chulldown was initiated at 0802. At 0822, LH2 slowfill to 2% was begun. The transition to LH2 fast fill occurred at 0835.

LO2 slow fill to 2% was initiated at 0854.

The 60% LH2 level indication (71.82% actual) was received at 0857 and recirculation start was initiated. The 98% LH2 level was achieved at 0905. After start of LH2, replenish at 0910, the recirculation pumps cavitated. Recirculation was stopped and the pre-valves opened. A subsequent attempt to start recirculation also resulted in pump cavitation. After a drawback, the pumps were restarted and performed satisfactorily. A more detailed discussion of the recirculation system problem and the corrective action is included in Section 4.1 of this report.

LO2 2% level reached at 0908 and fast fill was initiated.

At approximately 0930, leaks were noted on the eighth level of the stand. A hold in the loading operation was initiated at this time and the red crew dispatched to the stand to investigate. The leaks were repaired and the crew returned to the TCC.

LO2 fast fill was reinitiated at 1028 and terminated at the 98% level at 1109.

LH2 replenish was reinitiated at 1117.

A LO2 loading sensor special test was performed while instrumentation personnel performed measurement adjustments on the stand.

The instrumentation crew returned to the TCC at approximately 1330 and the count was resumed. Sequence 4 was initiated at 1334.

In Sequence 4, a problem was experienced in lighting the three free hydrogen burnoff system igniters. Engines #1 and #2 igniters lit satisfactorily, but the igniter for Engine #3 failed to ignite. A red crew was sent to the stand to investigate. Repeated attempts to ignite the #3 burner were unsuccessful. The crew was brought back and the decision made to proceed without the #3 igniter.



3.1 (continued)

The auto sequence was initiated at 1401 and continued without hold through the firing period. The engines ran for the planned duration.

Simultaneous drain of LO2 and LH2 was initiated at 1417. Drain was complete at 1534.

3.2 Test Events

Significant events for MPT S2-001 are presented in Table 3.2-1.

3.3 Facility

3.3.1 A post static firing inspection of the flame deflector and associated High Pressure Industrial Water System Plumbing was conducted. There was no structural damage found to either the deflector or associated plumbing. Likewise, the flame pattern exhibited no hot spots on the deflector surface.

3.4 Software

The MPT Software performed as expected. There was a failure of the FID buffer readout; however, this was considered a minor problem and had previously been documented as DRX0167-98. The problem has since been corrected by SMS MMN-0211.

3.5 Data Processing

The data processing for analog inputs to digital recording systems is working satisfactorily.

- (a) A few minor problems were encountered; however, and are corrected or in work via data squawks.
- (b) More attention was placed on wideband data for this test due to test duration and power level. The significant data anomalies fall into the wideband area such as:
 - (1) 16.5 Hertz noise on one CBW system (100 channels of data). The noise level is between six to ten percent of the total data range which interferes with data analysis. This problem is under investigation by the test data data acquisition facility.



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3.5 (continued)

- (2) A large number (34) of POGO measurements are not working or the signal is going into saturation. The saturation problem is probably an over range of instruments on approximately 20 channels with the rest of measurements under investigation via data squawks.
- (3) The Orbiter and test stand overpressure measurements are producing signatures which were not expected. No known reason exists at this time to explain data, but the problem is under investigation.
- (4) Four out of five acoustic measurements are not working properly. The measurements are under investigation via data squawks.



TABLE 3.2-1. SIGNIFICANT EVENTS FOR TEST MPT-S2

<u>EVENTS</u>	<u>TIME OF DAY</u>
Start Propellant Load	08:02.30
Chilldown in Progress	08:11.00
LH ₂ Solid 2% Going to Fast Fill	08:35.00
LH ₂ Solid 5% - Fast Fill	08:35.45
LH Solid 20%	08:54.00
LO ₂ Start Slow Fill (2%)	08:54.00
LH ₂ 60% Flashing	08:56.45
Start LH ₂ Recirc Pump	08:57.05
LO ₂ 2% Flashing	09:00.15
LH ₂ 80% Flashing	09:04.00
LH ₂ 98% Flashing	09:05.50
LO ₂ 2% Solid	09:08.50
LO ₂ Fast Fill Open 10% Solid	10:29.30
LO ₂ 20% Wet	10:36.00
LO ₂ 40% Wet	10:40.50
LO ₂ 60% Wet	10:49.00
LO ₂ 80% Flashing	10:53.10
LO ₂ 98% Flashing	10:59.50
LO ₂ 100% Flashing	11:02.15
LH ₂ 100% Flashing	11:02.50
Start Auto Sequence	11:02.40
Engine Ready	11:09.55
Engine Start	11:11.30
Run Time - #1 - 19.17	
#2 - 20.85	
#3 - 20.73	
Engine Off	
LH ₂ Prevalves Closed	14:13
Initiate Propellant Drain	14:17.30
LH ₂ Drainback in Progress	14:20.30
LO ₂ Drainback in Progress	14:30.00
LO ₂ Drain Complete	15:19.00
LH ₂ Drain Complete	15:34.40
M0005 Complete	15:35.45



4.0 ENGINEERING ANALYSIS

4.1 Propulsion Systems

4.1.1 Main Propulsion Systems (MPS) - Integrated

The Orbiter Main Propulsion Subsystem (MPS), utilizing three GFE Space Shuttle main engines (SSME), and assisted by two solid rocket boosters (SRB) during the initial phases of the ascent trajectory, provides the velocity increment and thrust vector control from liftoff to a predetermined velocity prior to orbit insertion. The MPS includes the SSME's, and has subsystem components installed on the External Tank (ET) as well as on the Orbiter. MPS operation begins with preparation for propellant loading and ends after landing. The MPS consists of the following sub-systems:

- a. Propellant Feed to Main Engines
- b. Propellant Fill and Drain
- c. Engine Pre-start Propellant Conditioning
- d. ET Pressurization Control
- e. Pneumatic Valve Actuation, Main Engine GHe Purge & Line Repressurization
- f. Main Engine GN2 Purge
- g. Propellant Management
- h. Space Shuttle Main Engines (GFE)
- i. Engine Heat Shield
- j. Pogo Suppression (not applicable to MPT S2-001)

All of the test objectives pertaining to the MPS delineated in the Detailed Test Plan for Test No. MPT-S2 were essentially met

The on-site quick look data review for static firing MPT-S2 noted the following anomalies:

- a. Cavitation of the LH2 recirculation pumps during the count-down. This was caused by back pressure in the H₂ vent system choking off the high point bleed flow. The site is issuing a CR to modify the vent system.
- b. The engine #3 nozzle was discolored. This is attributed to afterburning caused by a leaking main fuel valve. The valve has been replaced. The nozzle is okay as is.
- c. The engine #3 inlet pressure measurements shifted badly during the firing with the LH2 pressure approaching the red-line. This was predicted by SD instrumentation as these transducers are not insulated. They will be insulated for static firing #3.



4.1.1.1 Propellant Loading.

Simplified loading and instrumentation schematics for the LH_2 and IO_2 systems are presented in Figures 4.1.1.1-1 through -4; Figures 4.1.1.1-1 and -2 for LH_2 . These measurements represent the data which has been reviewed for this report. Timelines for the LH_2 and IO_2 tankings are included as Figures 4.1.1.1-5 and -6 respectively.

4.1.1.1.1 LH_2 Tanking Procedure.

The only restriction on hydrogen tanking was an ET maximum tank pressure of 20 psig to prevent a pressure cycle (the loading procedure was written with a 10 psig limit to insure that the 20 psig would not be violated)

- a. Perform initial facility and vehicle chill by flowing cold gas from the barge storage tank pressurization vaporizer through the system and out through the ET vent valve.
- b. Initially fill the facility and vehicle to the 2% level by pressurizing the barge storage tanks to 65 psig and flowing LH_2 into the system through the facility slow fill valve. Flow during this period was estimated to be about 1000 gpm.
- c. Fast fill to the 98% level by flowing through the facility fast fill valve. Flow during this period was approximately 12,350 gpm average.
- d. Top to the 100% level through the facility slow fill (FCV107) and replenish (LCV105) valves at a flow in excess of 1000 gpm.
- e. Maintain the 100% level with the replenish valve.

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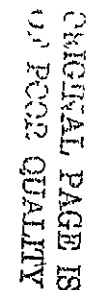
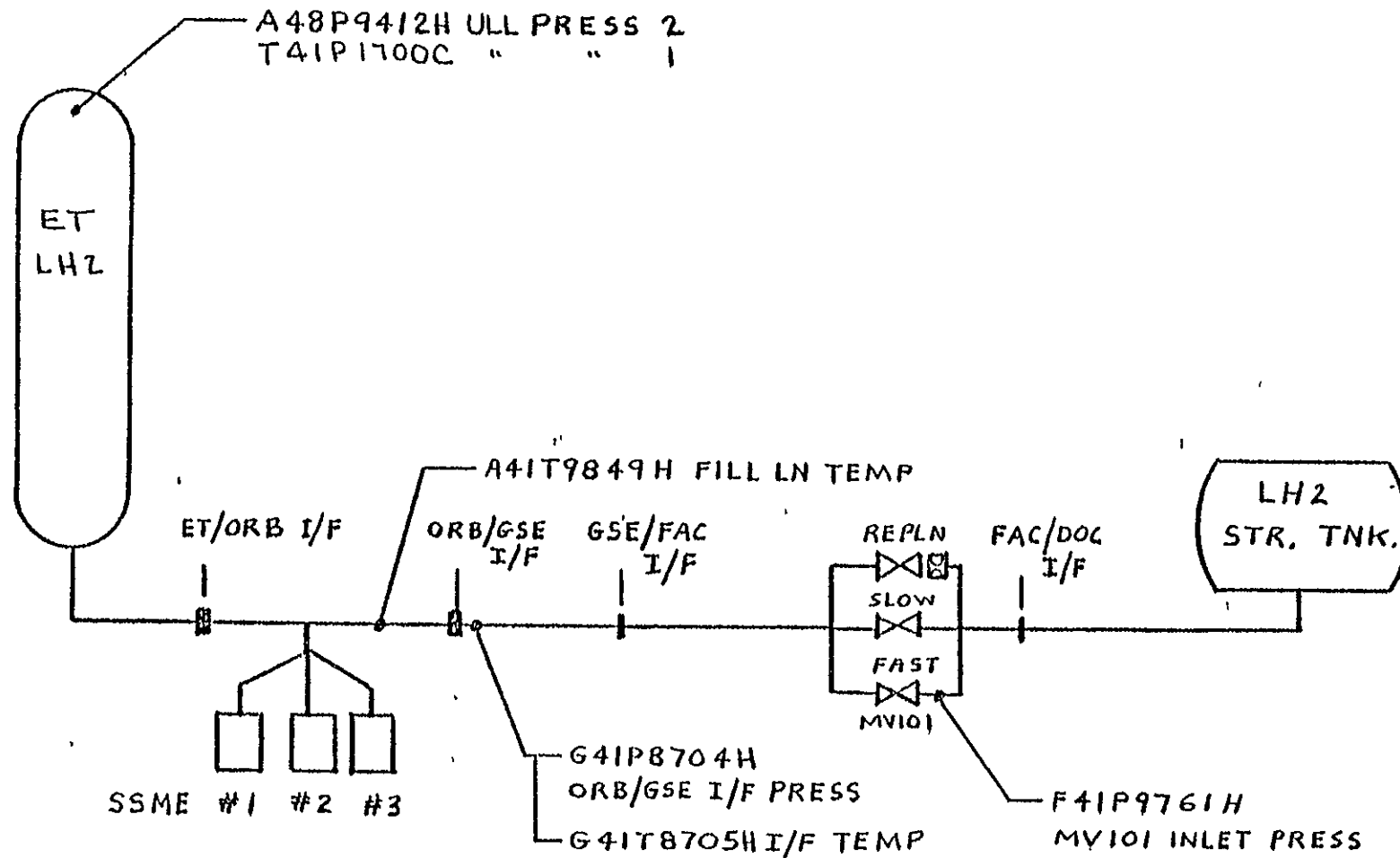


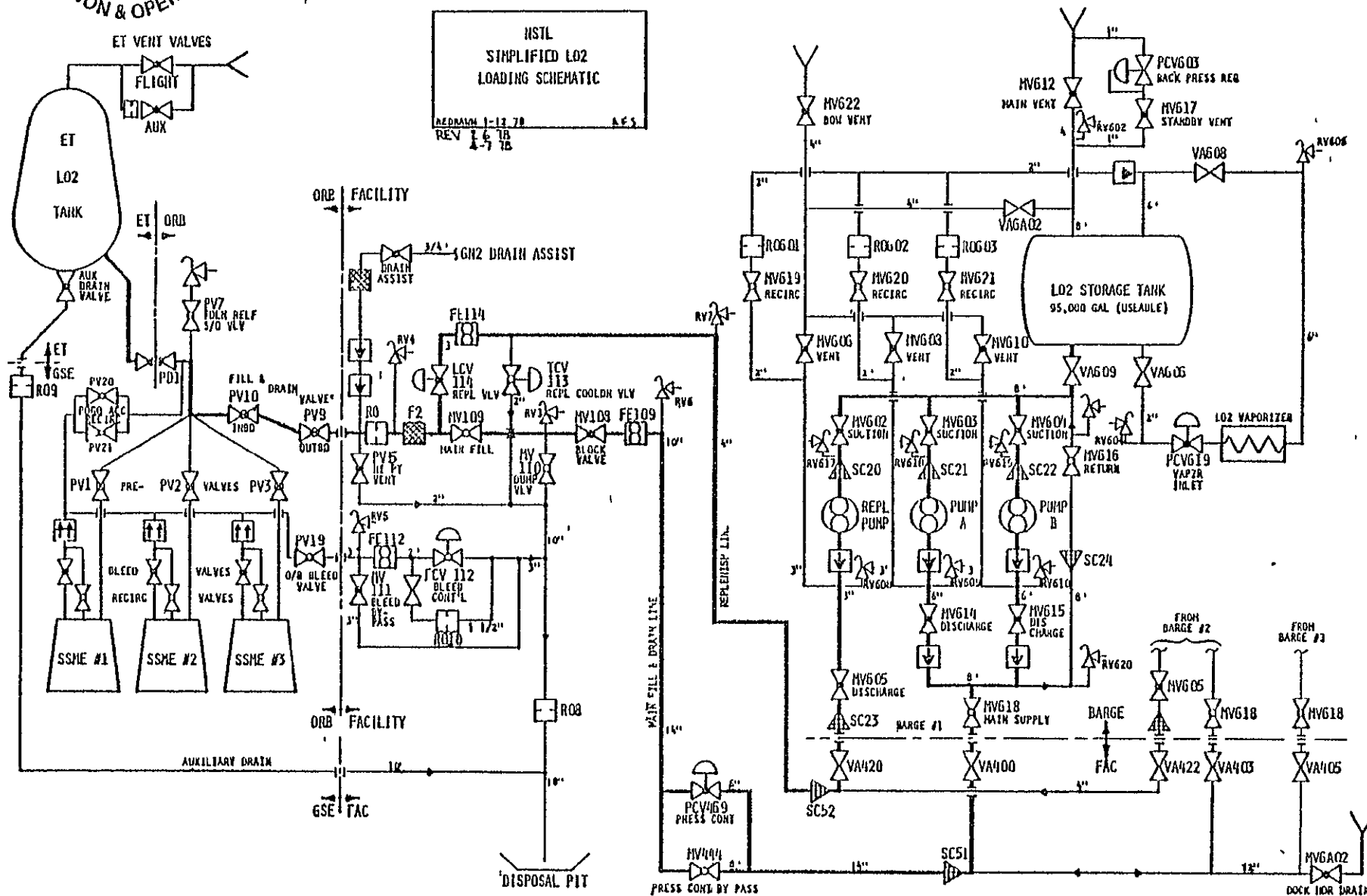
FIG. 4.1.1.1-2 LH2 INSTRUMENTATION SCHEMATIC



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FIG. 4.1.1.1-3 L02 SCHEMATIC

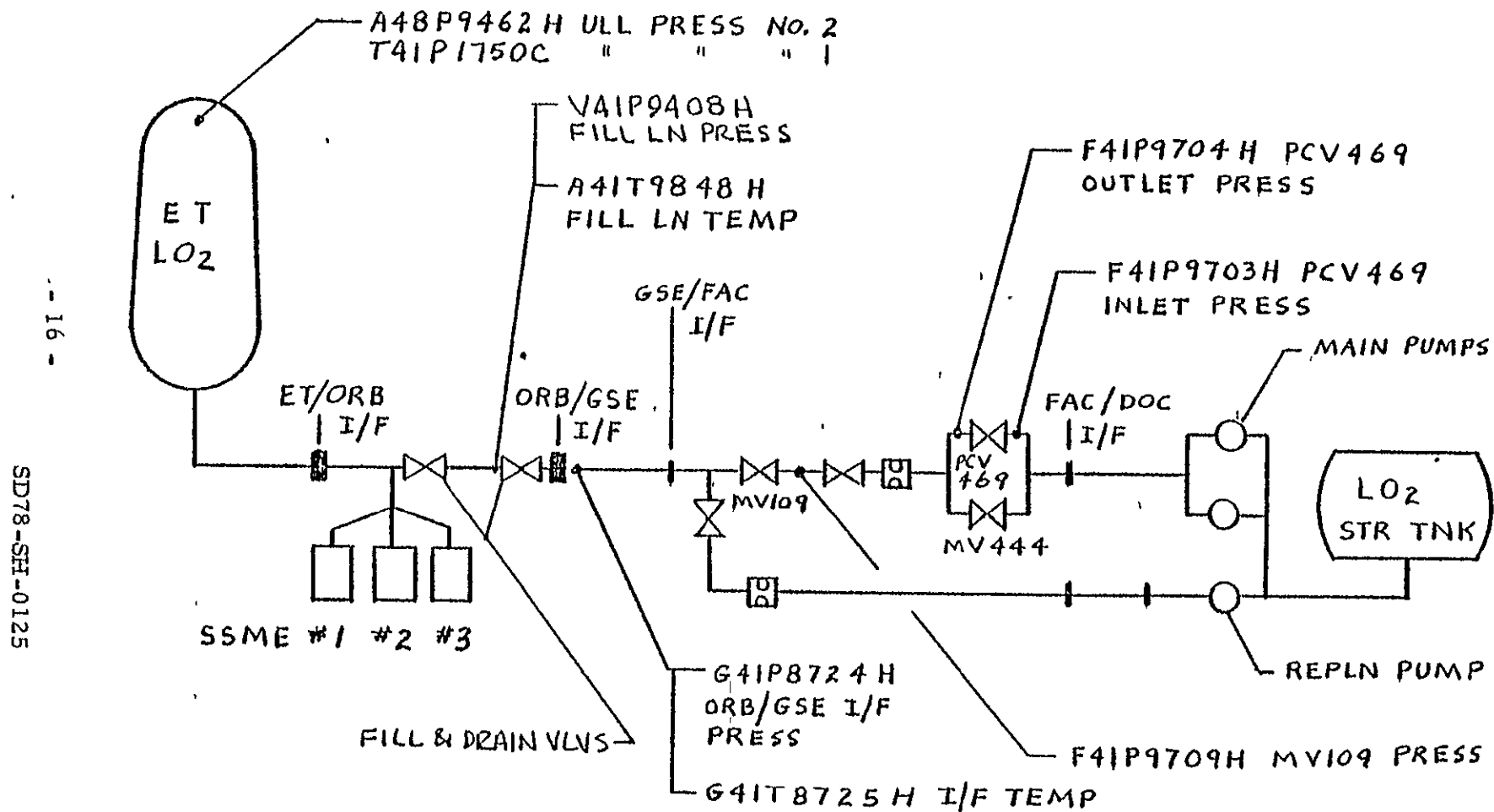


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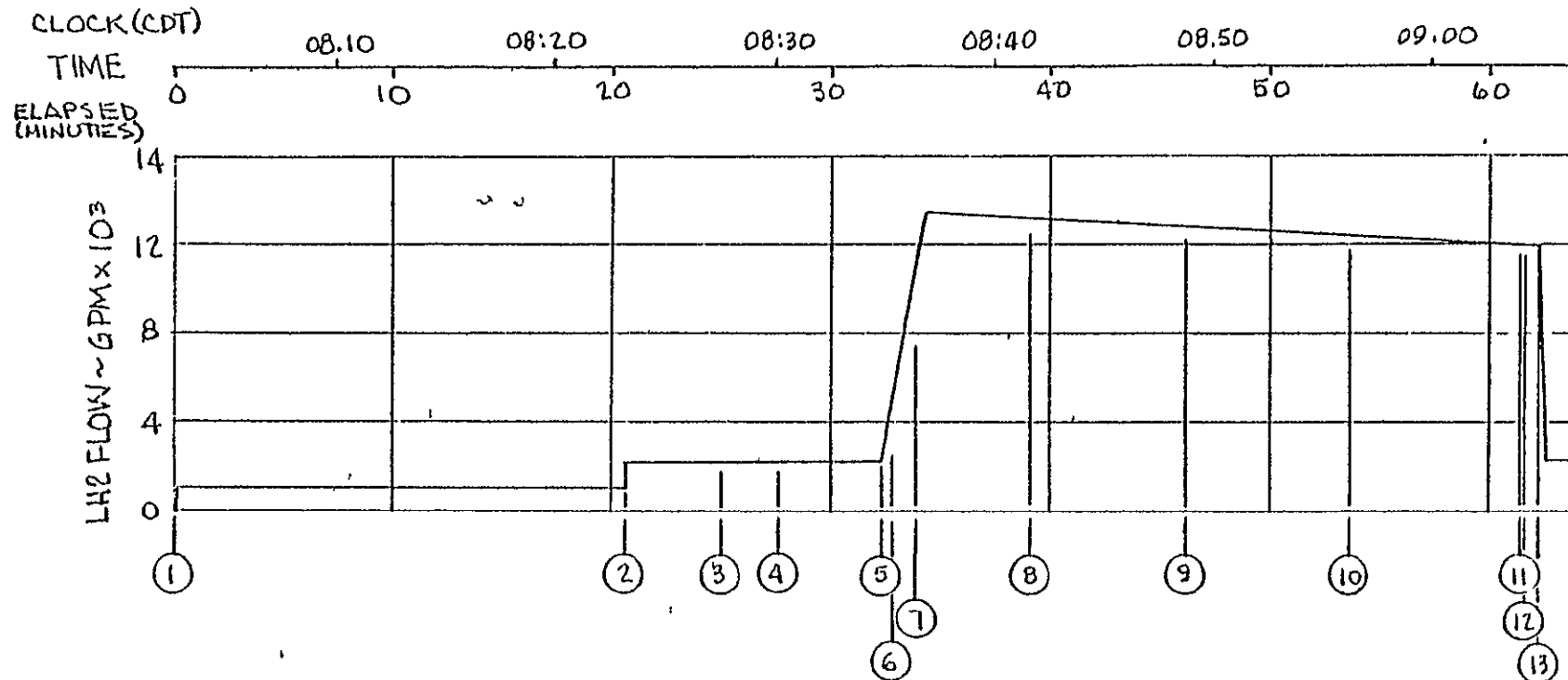
FIG. 4.1.1.1-4 LO2 INSTRUMENTATION SCHEMATIC



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5F-2
LH2 TANKING TIMELINE
5-19-78



- ① START FACILITY CHILL & FILL
- ② START ORB. CHILL & INITIAL FILL
- ③ LH2 @ 1/2 % SENSOR
- ④ " " 2 % "
- ⑤ START FAST FILL
- ⑥ LH2 @ 5 % SENSOR
- ⑦ " " 10 % "

- ⑧ LH2 @ 20 % SENSOR
- ⑨ " " 40 % "
- ⑩ " " 60 % "
- ⑪ " " 80 % "
- ⑫ " " 98 % "
- ⑬ STOP FAST FILL

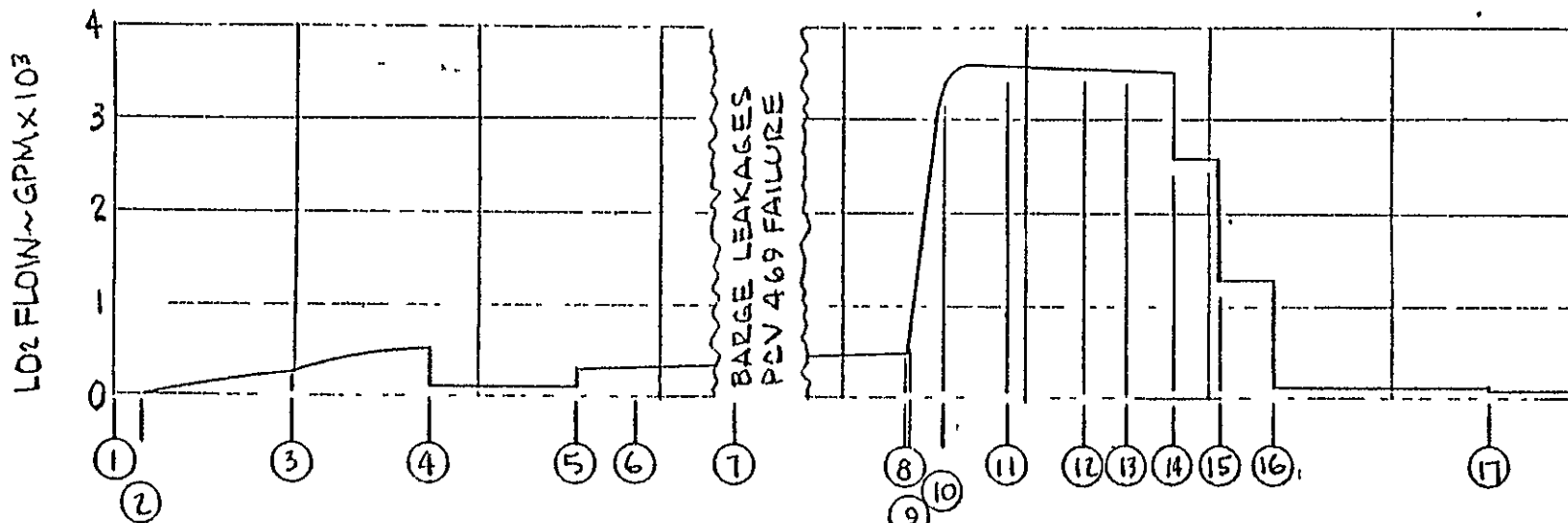
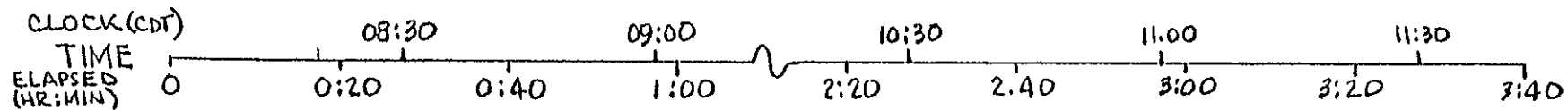
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SF-2

LO2 TANKING TIMELINE

5-19-78



- ① START LO2 CHILLDOWN
- ② START FAC CHILL & FILL (GRAVITY)
- ③ CONTINUE CHILL & FILL (PRESSURIZED)
- ④ START ORB CHILL/FILL (START REPL PMP)
- ⑤ START INITIAL FILL TO 2%
- ⑥ 2 % SENSOR
- ⑦ 5 % "
- ⑧ START FAST FILL
- ⑨ 10 % SENSOR
- ⑩ 20 % "
- ⑪ 40 % "
- ⑫ 60 % "
- ⑬ 80 % "
- ⑭ 1 BARGE MAIN PUMP SHUTDOWN
- ⑮ " " " " "
- ⑯ 98 % SENSOR - STOP FAST FILL
- ⑰ 100 % "



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FIGURE 4.1.1.1-6



4.1.1.1.2 LH2 Tanking Discussion

a. Timeline

The sequence of events for the LH2 tanking are listed below. The times of events were obtained from the Historian's Log except those designated (r) which are from the DEE. All times are referenced to T-0 of 78:139:14:10:56.010.

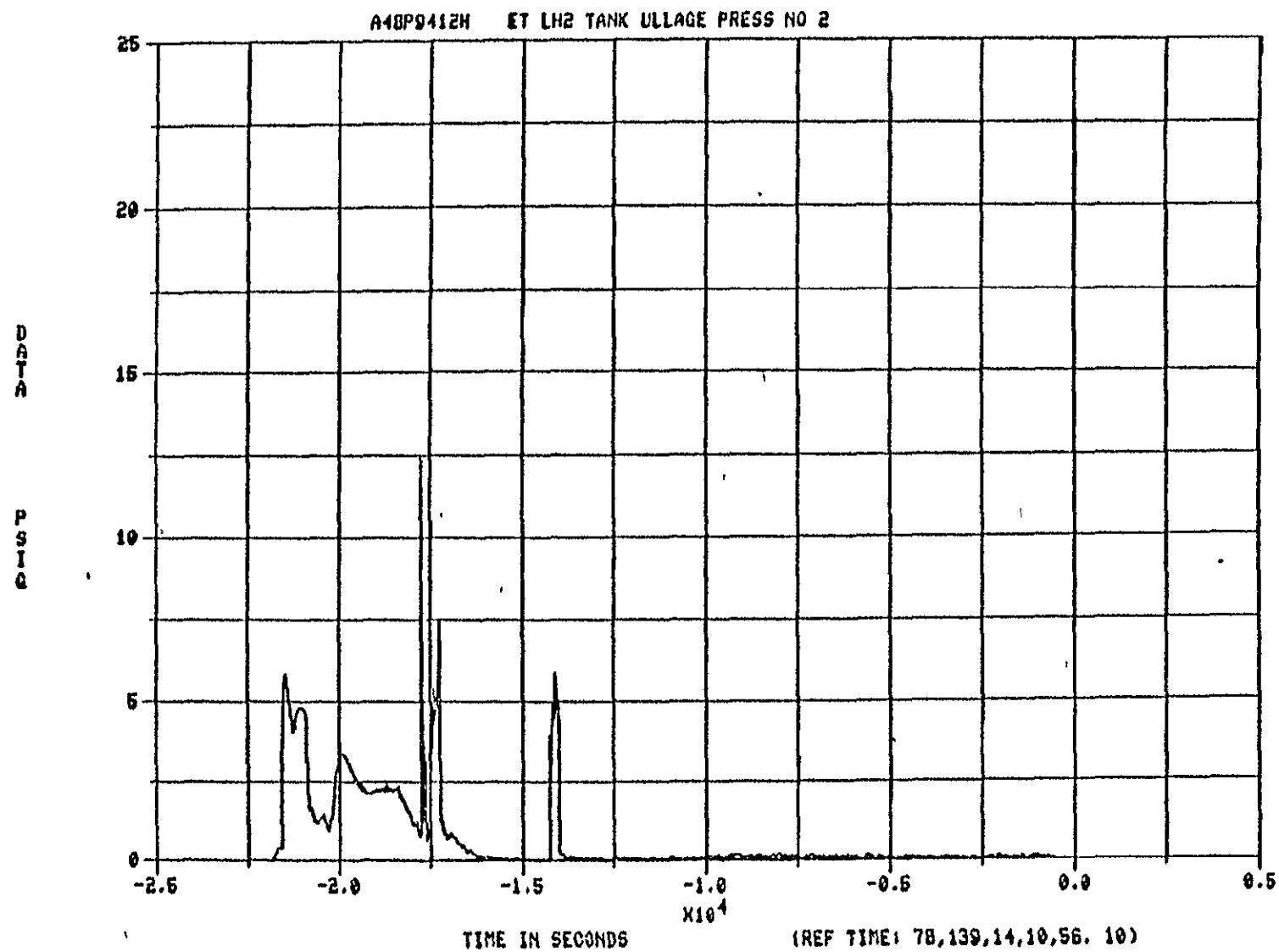
<u>Time, Seconds</u>	<u>Event</u>
-22,101	Start LH2 chilldown
-20,871	Start LH2 slow fill
-20,575 (+)	LH2 at 0.5% sensor
-20,470 (+)	LH2 at 2% sensor
-20,253 (+)	LH2 at 3% sensor
-20,239 (+)	LH2 at 1% sensor
-20,164	Start LH2 fast fill
-20,137	LH2 at 5% sensor
-20,100 (+)	LH2 at 4% sensor
-20,098 (+)	LH2 at 10% sensor
-19,773 (+)	LH2 at 20% sensor
-19,341 (r)	LH2 at 40% sensor
-18,900 (r)	LH2 at 60% sensor
-18,859	Recirc pumps on
-18,459 (+)	LH2 at 80% sensor
-18,411	LH2 at 98% sensor
-18,376 (+)	LH2 at 100% sensor
-18,369 (r)	LH2 at 100.3% sensor
-18,366	Stop fast fill
-18,347 (+)	LH2 at 101.0% sensor

b. ET LH2 Ullage Pressure

Figure 4.1.1.1-7 - A48P9412H, ET LH2 ullage pressure 2.

For system chilldown and tanking the maximum ET ullage pressure occurs during facility chill down. The measured value of 5.8 psig agrees with the RI computer prediction of 5.4 psig.

A second smaller pressure peak of 3.4 psig occurs during fast fill. Several additional pressure peaks are indicated at approximately T-17,500 and T-14,000 sec. These were a result of ullage pressurization associated with recirc pump restart attempts (See preconditioning discussion). All pressures are below the maximum ET cycle limit of 20 psig. No anomalies were observed in ullage pressure during the LH2 loading.



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FIG. 4.1,1.1-7



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c. MPS LH2 F/D line and Orb/GSE I/F Temperature

Figure 4.1.1.1-8 - 441T9849H, MPS fill line temperature

Figure 4.1.1.1-9 - 641T8705H, Orb/GSE I/F temperature

Both measurements indicate that the hydrogen reached liquid temperature at approximately -20,750 seconds. The off-scale high indications subsequent to -17,000 are associated with recirc pump attempted starts. (see pre-conditioning)

d. Orb/GSE LH2 I/F and Fast Fill Valve (MV101) Pressures

Figure 4.1.1.1-10 - 641P8704H, Orb/GSE I/F Pressures

Figure 4.1.1.1-11 - 741P9761H, Fast Fill Valve (MV101)
inlet pressure

The pressure time histories indicate several anomalies. The first pressure spike at -20,164 seconds (Figure 4.1.1.1-10) is caused by the opening of the main facility fill valve (MV101) and the passage of warm LH2 (trapped at the valve inlet) through the system. This is normal and expected.

With fast fill completion, facility valve MV101 was closed, followed almost immediately by the opening of the Orbiter topping valve and the closing of the inboard fill and drain valve. This sequence caused the pressure surge shown on figure 4.1.1.1-10 at -18,340 sec. A second peak was seen at -17,650 seconds with the closure of the outboard fill and drain valve.

The two pressurization cycles, shown in both figures, between -16,000 seconds and -14,000 seconds were performed to permit leak checking of the facility drain lines in which a major hydrogen leak had been detected. Red crew personnel were able to sufficiently reduce the flow from a leaking Marmon flange that the test was resumed. Venting of the transfer system, prior to the crew entering the area, is shown in both figures at approximately -17,000 seconds. At about -10,000 seconds flow to the vehicle was reintroduced and hydrogen loading was satisfactorily completed.

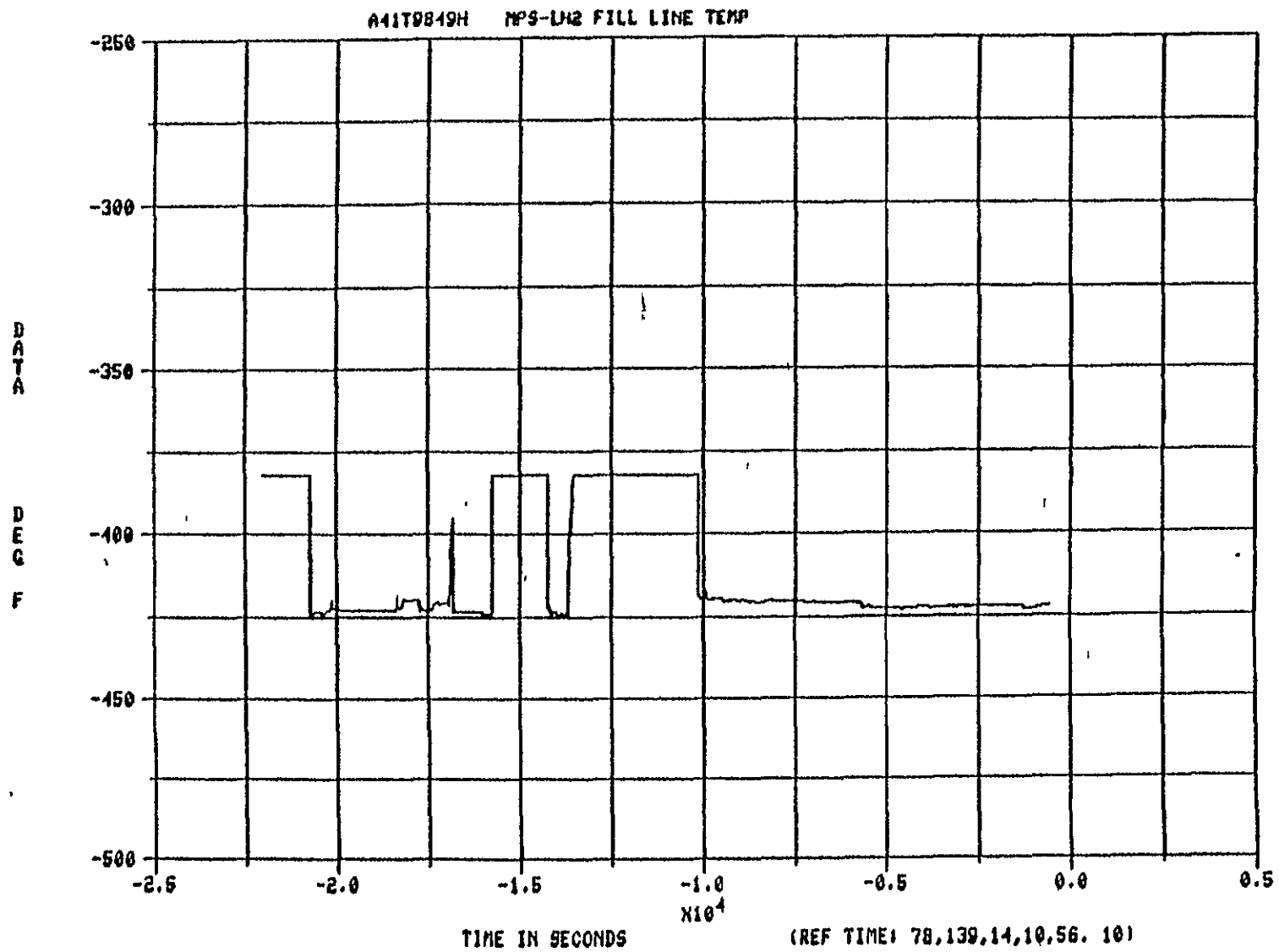
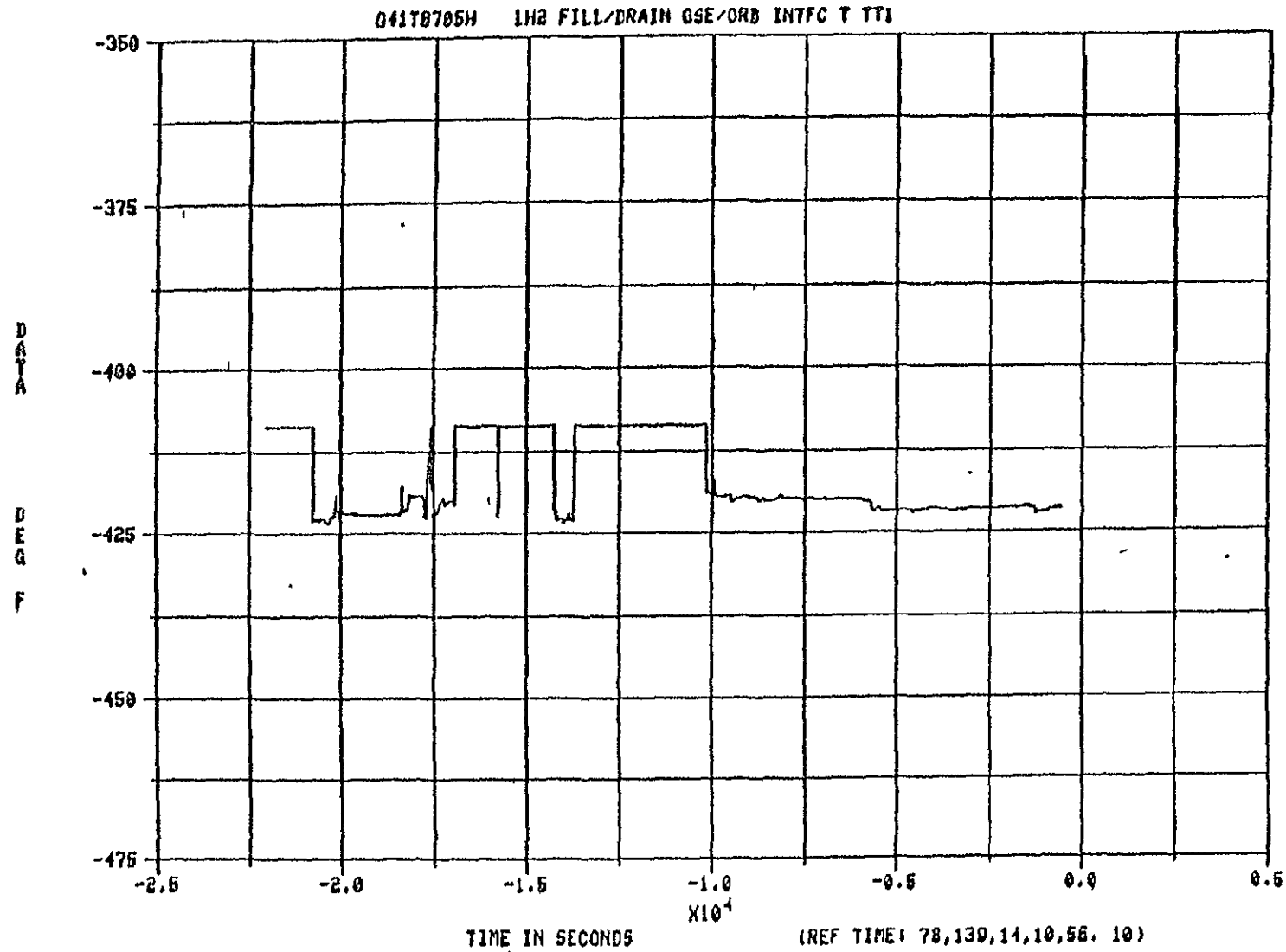


FIG. 4.1.1.1-8

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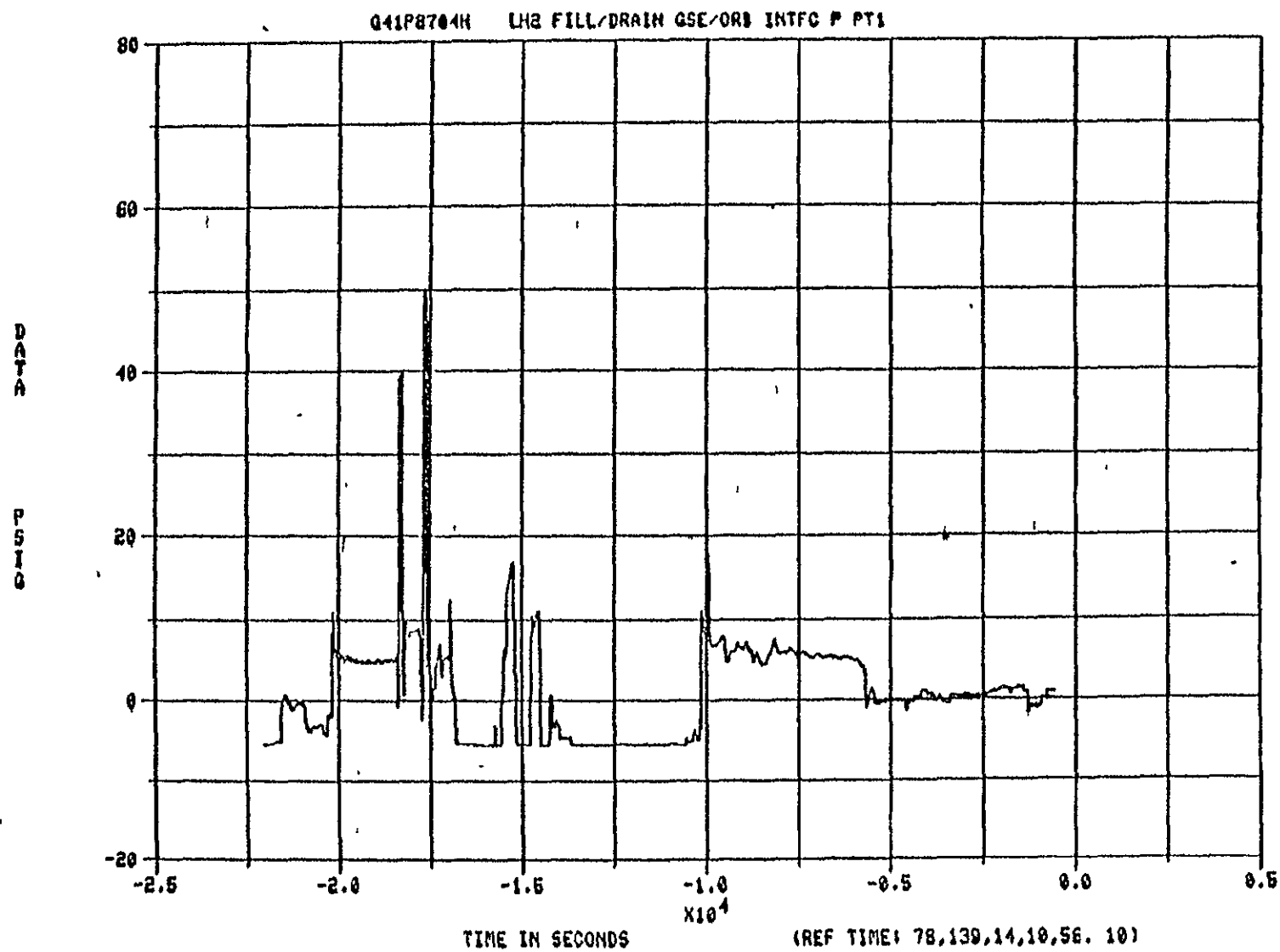
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FIG. 4.1.1.1-9

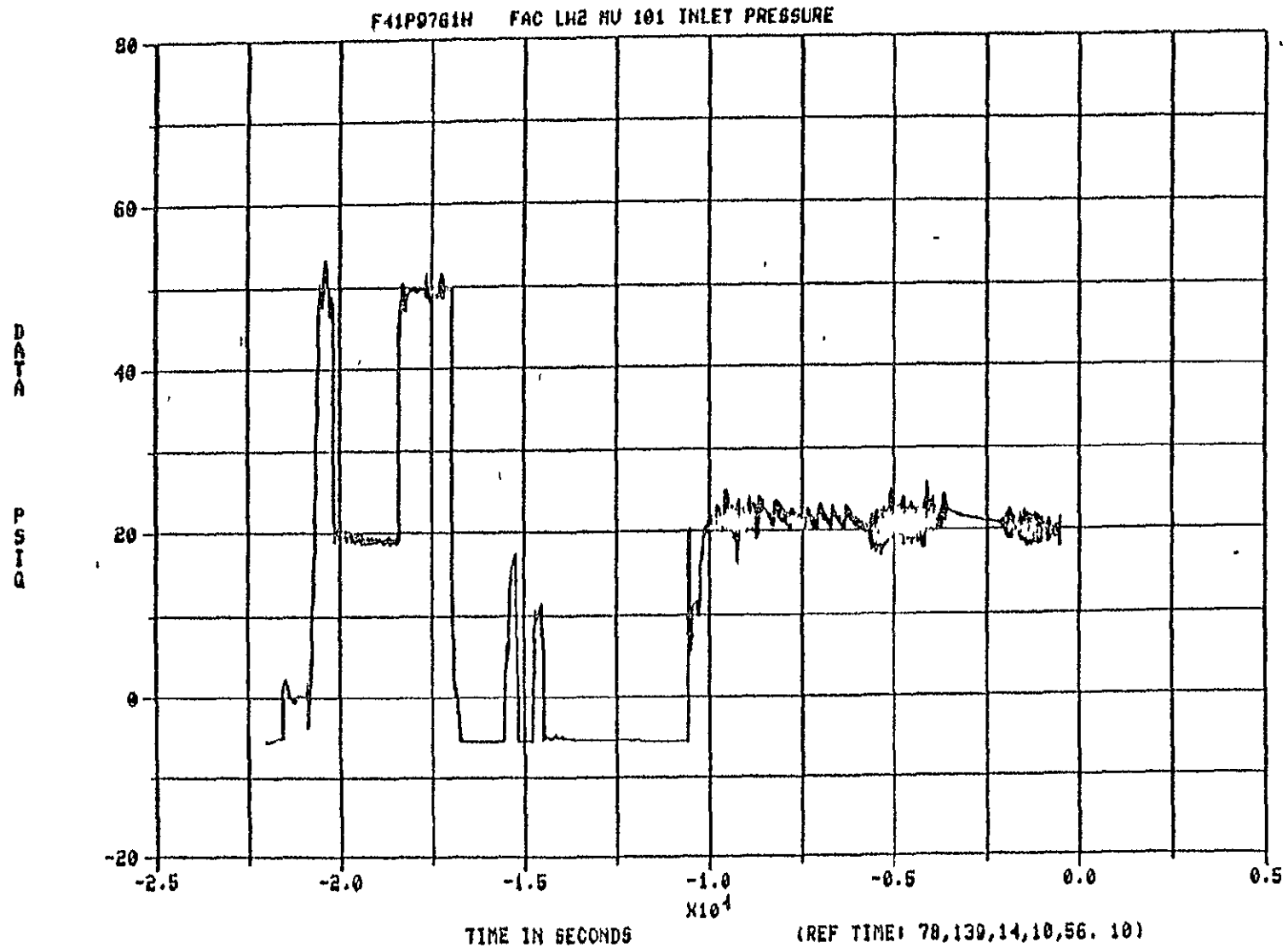


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FIG. 4.1.1.1-10

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FIG. 4.1.1,1-11

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e. Flowrate

No flowmeter is installed in the LH2 main fill system so flow-rates must be determined from the point sensors in the ET LH2 tank or from the delta P sensors. As of this writing the delta P data has not been evaluated. The following average flow-rates between point level sensors is based on the first flash of each sensor as recorded in the historians log (DEE data was inconsistent for this purpose). This is reflected in Figure 4.1.1.1-5.

<u>Level From-To</u>	<u>Volume (Gallons)</u>	<u>Time (Minutes)</u>	<u>Flow (GPM)</u>
0.5% - 2%	5,686	2.60	2,187
2% - 5%	11,449	5.18	2,209
5% - 10%	8,084	1.10	7,349
10% - 20%	68,814	5.30	12,984
20% - 40%	90,940	6.98	13,022
40% - 60%	90,901	7.52	12,093
60% - 80%	91,327	7.78	11,734
80% - 98%	9,941	0.83	11,929

f. LH2 Point Sensor Operation

As of this writing, analysis of the point sensor operation is not complete. Due to computer buffer saturation, DEE data on point sensor operation is rejected. PCM and SATS data from the Slidell Computer Complex, during the tanking operation, is similarly unusable due to sampling rates and "thinning" procedures. Fortunately, the discrete data from the sensors in the 98% to 101% areas is recorded on PCM and can be made available by special request. This data will be analyzed upon receipt.



4.1.1.1.3 LO₂ Tanking Procedure

Restrictions on LO₂ tanking were: (a) maximum flowrate limited to 3500 gpm to prevent flow induced vibration in the Orbiter/GSE disconnect spoolpiece bellows, (b) maximum ET LO₂ tank pressure was limited to 18 psig to avoid creating a tank pressure cycle (the procedure was written with a 16 psig limit to insure that the 18 psig would not be violated), and (c) minimum ET LO₂ tank pressure at tank levels above 10% was restricted to 0.5 psig to meet tank structural requirements.

- a. Initially chill the facility lines by a gravity flow of LO₂ from the vented barge storage tanks out through the system dump valve (MVL10) and through the ET.
- b. Continue facility chill by pressurizing the barge storage tanks to 38 psig.
- c. Initiate Orbiter chill and fill by bringing on one 250 gpm replenish pump, throttling flow with the replenish valve, LCV 114, and venting the chilldown vapors through the ET LO₂ tank vent valve. Maintain LO₂ at Orbiter ECO sensors.
- d. Fill the ET to the 2% level utilizing the full flow capacity of the 250 gpm replenish pump.
- e. Fill the ET to the 98% level utilizing three 1000 gpm main pumps (one from each barge) and one 250 gpm replenish pump.
- f. Top to the 100% level with one 250 gpm pump.
- g. Maintain the 100% level with the replenish system.

4.1.1.1.4 IO₂ Tanking Discussion

The IO₂ loading system performed satisfactorily. Several large leaks were discovered on the IO₂ Barges but were such that they could be reduced to an acceptable level. No other serious anomalies were noted.

a. Timeline

The sequence of events for the IO₂ tanking is listed below. The times of events were obtained from the Historian's Log and from the DEE (-). All times are referenced to T-0 of 78:139:14:10:56.010.

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-22,101	Start IO ₂ chilldown
-21,926	Start IO ₂ gravity chill
-20,986	Pressurize barge storage tanks
-20,031	Start repl. pump-initiate Orb chill/fill
-19,055	Start initial fill to 2%
-18,690(+)	IO ₂ 2% sensor
-18,606(+)	IO ₂ 3% sensor
-17,800	PCV469 Failure
-16,641	IO ₂ 5% sensor
	IH ₂ System Problems
-13,285	Start fast fill
-13,273(+)	IO ₂ 10% sensor
-13,057(+)	IO ₂ 20% sensor
-12,632(+)	IO ₂ 40% sensor
-12,156(+)	IO ₂ 60% sensor
-11,888(+)	IO ₂ 80% sensor
-11,541	Shutdown one 1000 gpm pump
-11,226	Shutdown second 1000 gpm pump
-10,901(+)	IO ₂ 98% sensor
-10,846	Start Topping to 100%
- 9,763(-)	IO ₂ 99.85% sensor
- 9,725(+)	IO ₂ 100% sensor
- 9,580(-)	IO ₂ 100.15% sensor

o. IO₂ ET Ullage Pressure

Figure 4 1.1.1.12 - AL8P9462H, ET Ullage Pressure No. 2

IO₂ ET ullage pressure is as expected during chilldown and filling of the facility, orbiter and ET. The maximum ullage pressure of 2.4 psig occurs during facility chilldown. The small rise in pressure at about -19,000 sec. occurred during initial tank fill. At approximately -16,500 seconds the Primary ET Vent Valve was closed putting the auxiliary vent line orifice into control. This back pressure is required for tank structural stiffness. In preparation for the start of fast fill, the primary vent was opened (-13,300 sec.) The tank vented before the IO₂ barge pumps were brought up to speed. At the end of fast fill, the primary vent was again opened, putting the orifice back in control for the remainder of the prefiring period.

The pressures are always below the ET maximum cycle limit of 18 psig and above the tank minimum of .5 psig when the tank level is above 10%.

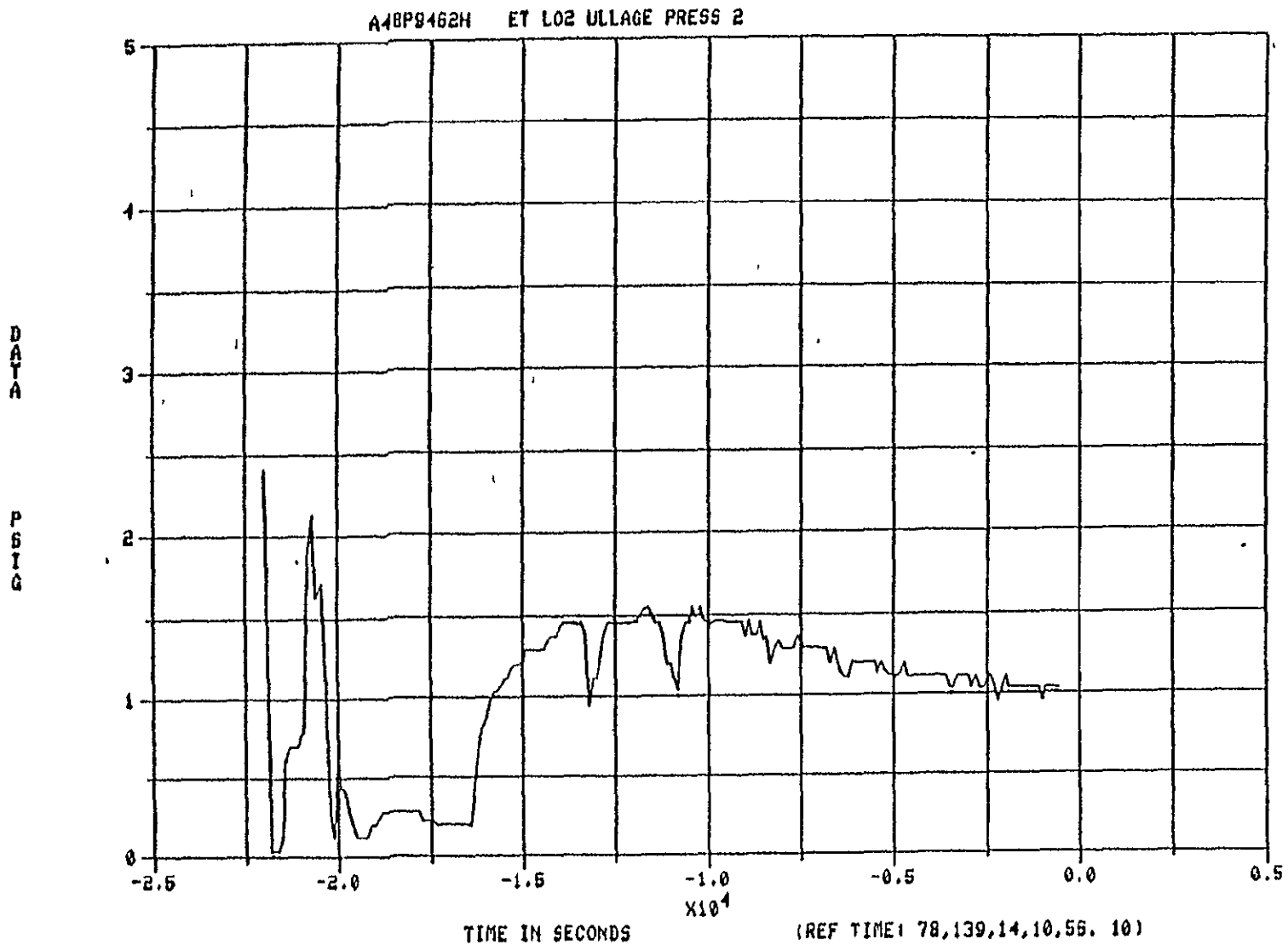
c. Fill Line Temperature

Figure 4.1.1.1-13 - G41T8725H, Orb/GSE I/F Temperature

The data indicates that liquid O₂ arrived at the Orb/GSE/I/F

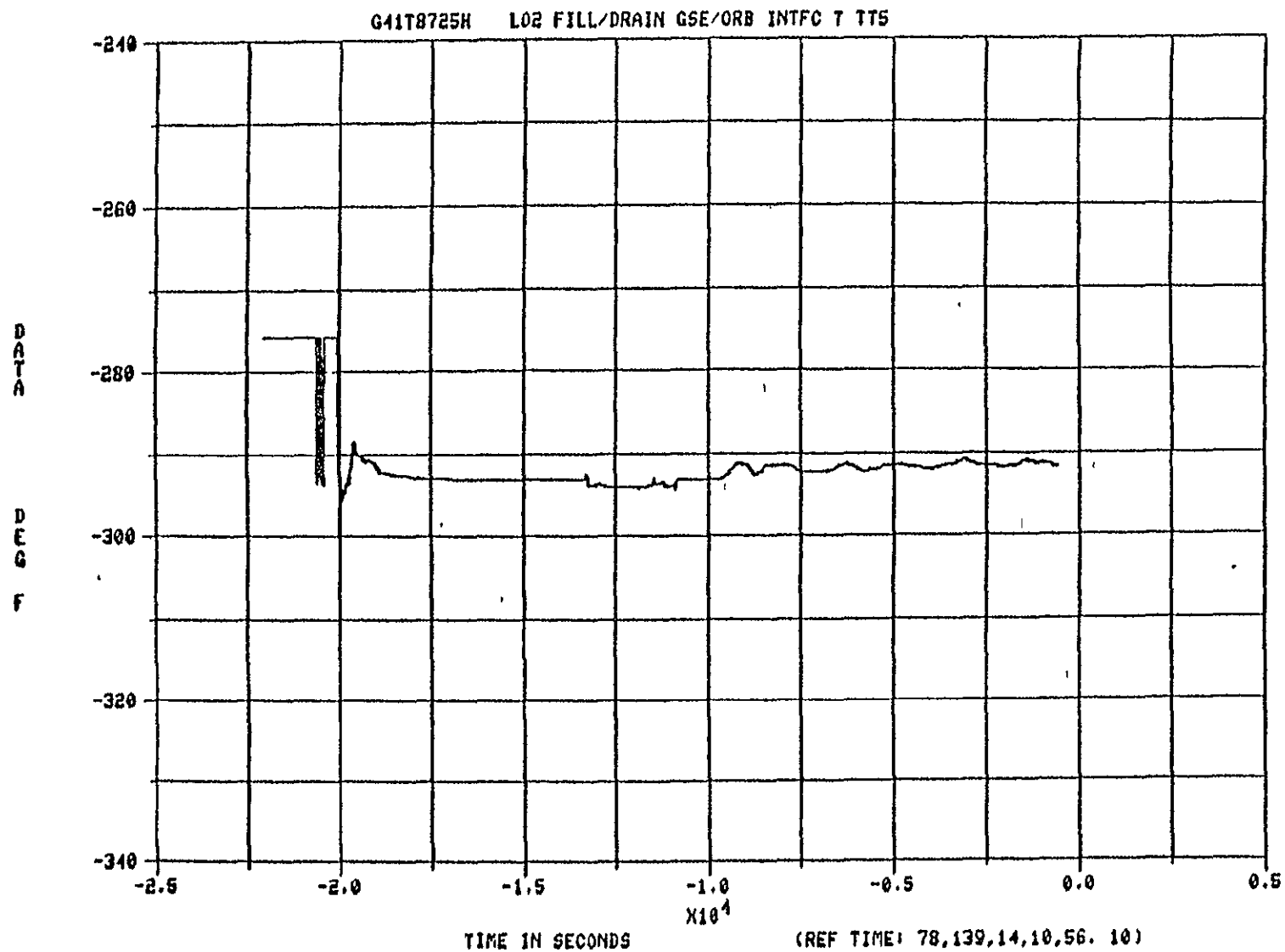
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FIG. 4.1.1.1-12



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FIG. 4.1.1.1-13



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at approximately -20500 seconds prior to bringing the replenish pump on line at -20031 seconds. A rise in temperature is seen after the replenish pump comes on line

d. Orbiter and Facility Line Pressure

Figure 4.1.1.1-14 V41P9408H, MPS LOX Fill Line Press P227

Figure 4.1.1.1-15 G41P8724H, Orb/GSE/I/F Pressure

Figure 4.1.1.1-16 F41P9709H, Main Fill Valve (MV109) Pressure

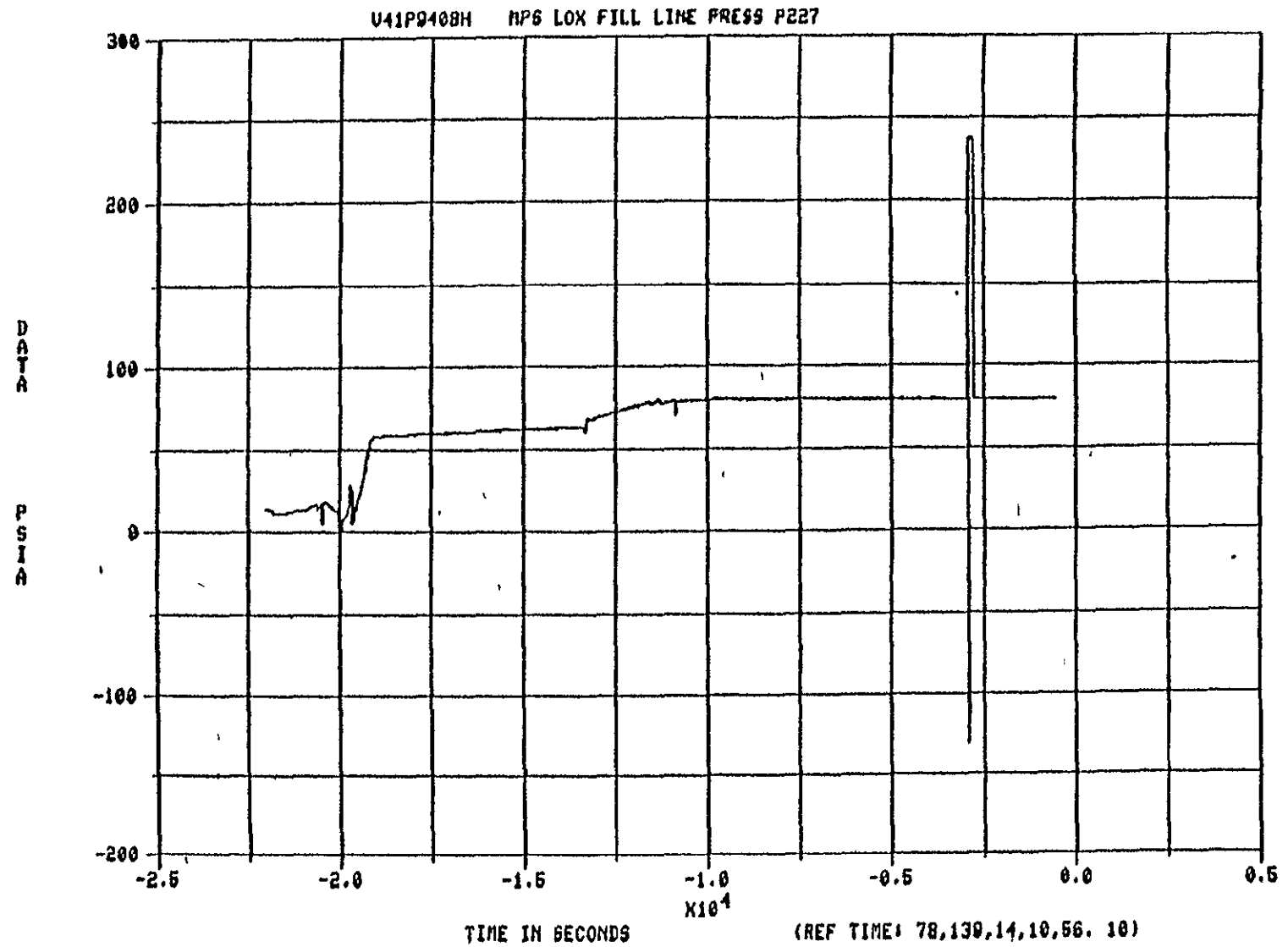
Figure 4.1.1.1-17 F41P9704H, PCV469 Outlet Pressure

The orbiter and facility line pressures appear to be normal when compared with the sequence of events. Two anomalies have been identified during data review. They are:

- (1) On Figure 4.1.1.1-14 a pressure spike at approximately -3000 seconds is indicated. Review of all available data both upstream and downstream of this measurement, as well as discrete data, does not support this apparent anomaly. It has been concluded that the "spike" is bad data.
- (2) Figure 4.1.1.1-15 shows a significant reverse pressure spike at approximately -11,000 seconds. Investigation has shown this to be the result of valve sequencing such that the facility dump valve (MV110) came open before the main fill valve (MV109) reached the closed position.

e. Flowrate

The data received from the facility flowmeters was inconclusive so that flowrates must be determined from the point sensors in the ET LO₂ tank or from the delta P sensors. The following average flowrates between point level sensors is based on the first flash of each sensor. Delta P data confirms the flow rates. This is reflected in Figure 4.1.1.1-6. Because of a number of LOX leaks in the dock/barge areas, the tanking procedure had to be extended before the start of Fast Fill. During Fast Fill the 3500 gpm flow limitation was exceeded slightly (approximately 3600 gpm max.) The test conductor was maintaining 3500 gpm as indicated to him by a panel meter. This is well within the meter tolerance.



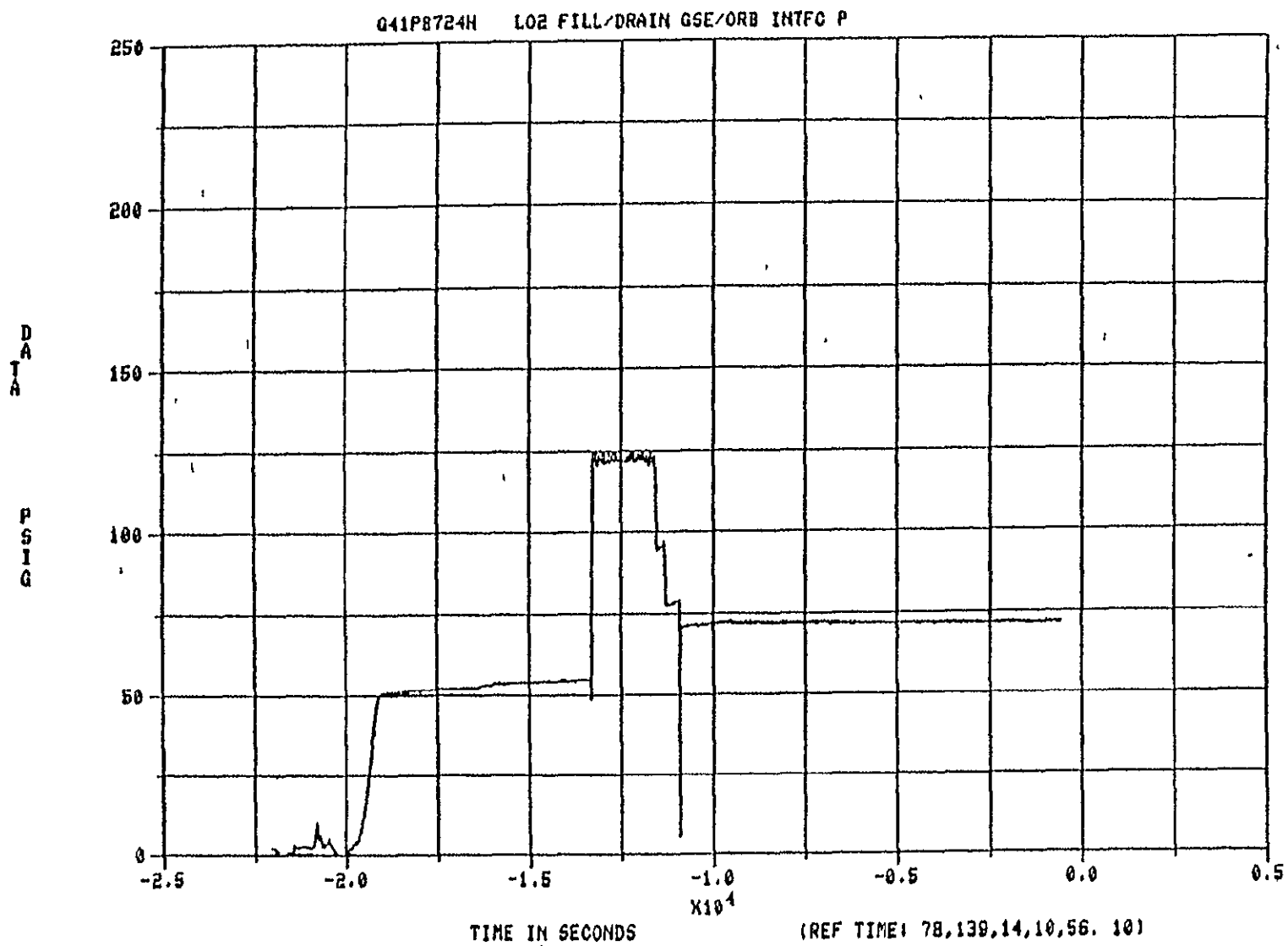
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FIG. 4.1.1.1-14

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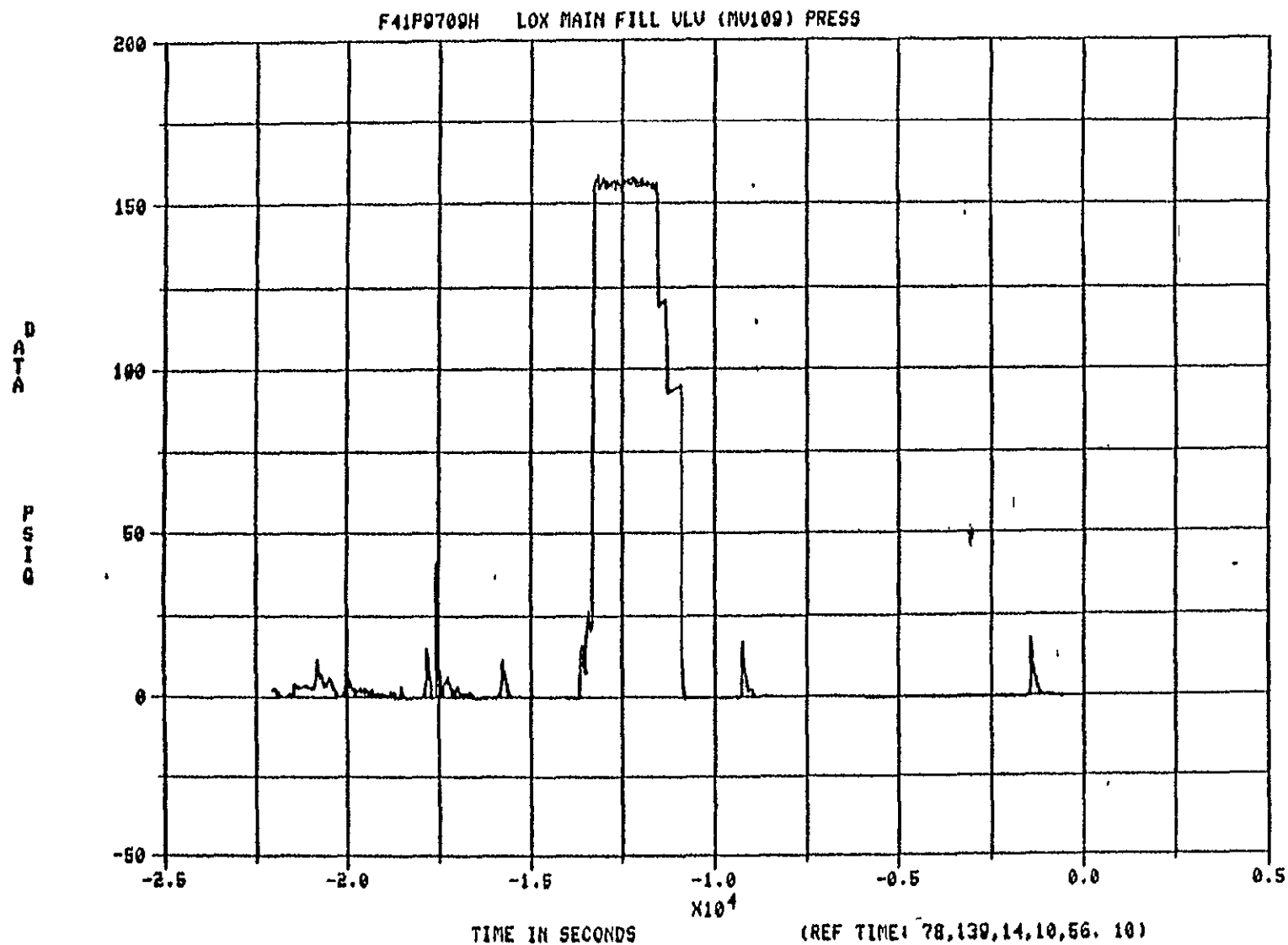
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FIG. 4.1.1.1-15



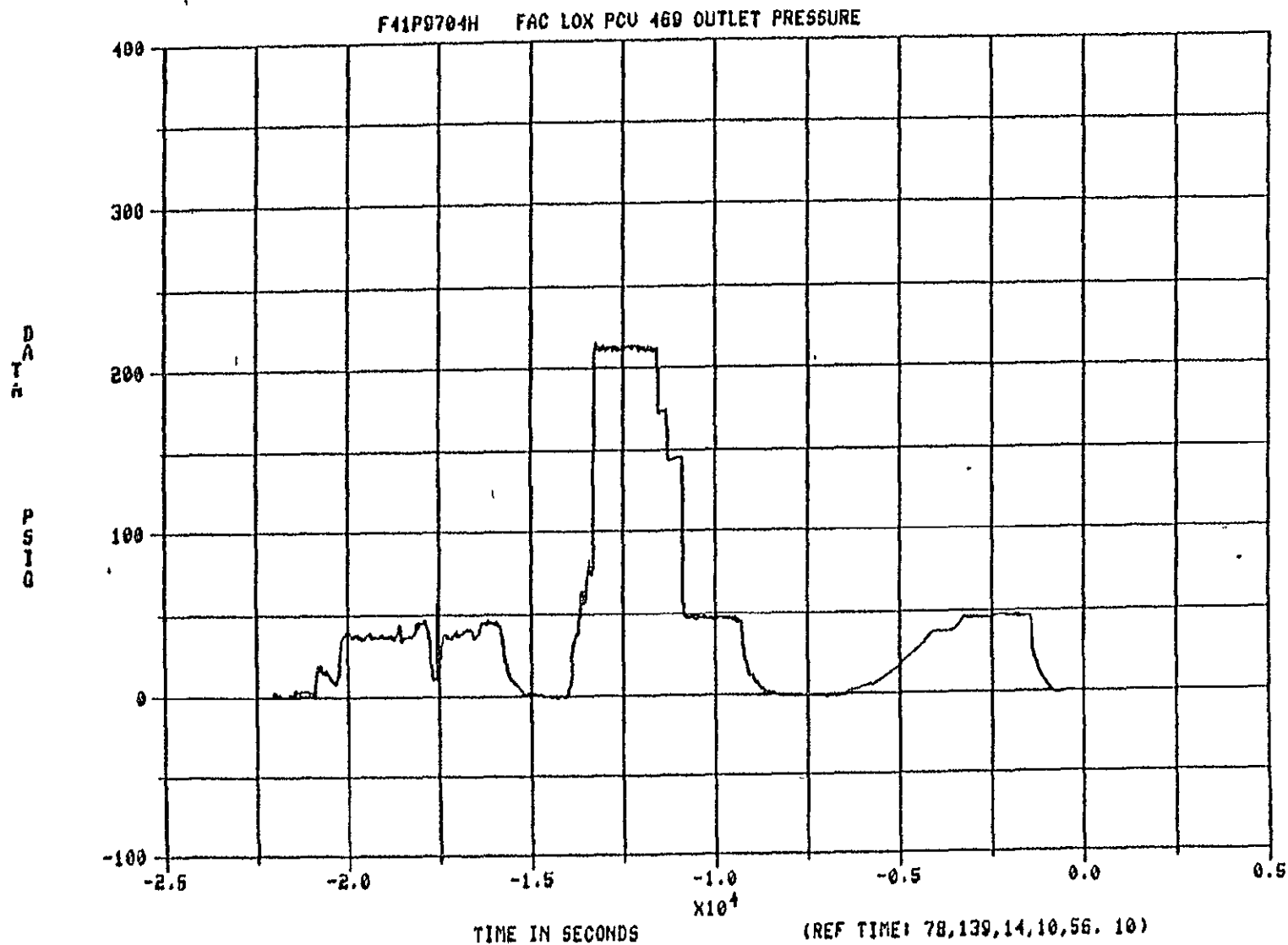
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FIG. 4.1.1.1-16

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FIG. 4.1.1.1-17



Level From-To	Volume (Gallons)	Time (Minutes)	Flow (GPM)
2% - 5%	4,241	34.15	124
5% - 10%	11,908	56.13	212
10% - 20%	12,949	3.60	3597
20% - 40%	25,018	7.08	3532
40% - 60%	27,838	7.93	3509
60% - 80%	15,670	4 47	3508
80% - 98%	40,095	16.45	2437
98% - 99.85%	2,651	18.97	140
99.85% - 100%	215	0.63	339
100% - 100.15%	215	2.42	89

f IO₂ Point Sensor Operation

As was stated for LH₂, as of this writing point sensor operation has not been completely evaluated due to a lack of adequate data. The sensor operation in the top of the ET IO₂ tank will be evaluated from PCM data upon receipt of that data.

4.1.1.1.5 LH₂ Replenish

Replenish flowrates are unknown because no useful information was received from flowmeter FE105.

4.1.1.1.6 IO₂ Replenish

The output from the IO₂ replenish flowmeter was inconclusive. However, no other anomalies are known.

4.1.1.1.7 LH₂ System In Auto Sequence and Engine Firing

The LH₂ loading system performed as expected.

4.1.1.1.8 IO₂ System In Auto Sequence and Engine Firing

The IO₂ loading system performed as expected.

4.1.1.1.9 LH₂ Detanking Procedure

The only restriction on the off-loading of LH₂ was that the ET LH₂ tank ullage pressure was not to exceed 16 psig.

- Configure the barges for drainback by opening tank vents and main line valves.
- In the test stand, open the main fill valve (MV101)
- Open the Orbiter outboard fill and drain valve.
- Pressurize the ET LH₂ tank to not greater than 10 psig.

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- e. Open the Orbiter inboard fill and drain valve and drain back to barge. Do not increase ET tank pressure above 16 psig.

4.1.1.1.10 IH_2 Detanking Discussion

Drain of the IH_2 tank was accomplished without incident, as can be seen in Figure 4.1.1.1-18, IH_2 tank ullage pressure. Times on the chart are referenced to T-0. The average flow was 7500 gpm.

4.1.1.1.11 IO_2 Detanking Procedure

Restrictions on off-loading of IO_2 were that flow was not to exceed 3500 gpm (as controlled by Orb/GSE interface fill line orifice), ET IO_2 tank initial ullage pressure not to exceed 7 psig (to establish proper inlet conditions to the flow limiting orifice), and that the Orbiter fill and drain valves were not to be operated with a delta P across either of them in excess of 50 psid

- a. Open the outboard fill and drain valve after the first pressurizing between it and the facility main fill valve (MV109) to equalize pressure across PV9. (Both the inboard and outboard fill and drain valves are closed at the end of auto-sequence)
- b. Close main dump valve (MV110), pressure control valve (PCV469) and pressure control bypass (MV444)
- c. Open MV109 and block valve (MV108).
- d. Pressurize main fill line to reduce delta P across inboard fill and drain valve
- e. Open inboard fill and drain valve, MV444 and PCV469 sequentially, but in rapid order.

4.1.1.1.12 IO_2 Detanking Discussion

Off-loading of IO_2 was accomplished as expected and without incident as can be seen by Figures 4.1.1.1-19, ET IO_2 Ullage Pressure, and 4.1.1.1-20, Orbiter IO_2 Fill Line Pressure.

Detanking was initiated with a 7 psig ullage pressure and was increased to 9 psig after approximately 2 minutes. This is sufficient time to reduce the IO_2 head in the tank so that the inlet pressure to the flow limiting orifice does not cause flow to exceed 3500 gpm. Average drain flow was 2600 gpm.

The pressure rise in the IO_2 Fill Line (Figure 4.1.1.1-20), until the opening of the outboard fill & drain valve at approximately 950 seconds, was due to trapped IO_2 in the line bellows and valves. This condition is not anomalous, but the magnitude of the pressure is greater than will be seen in flight because of the shorter duration of a locked-up condition for flight.

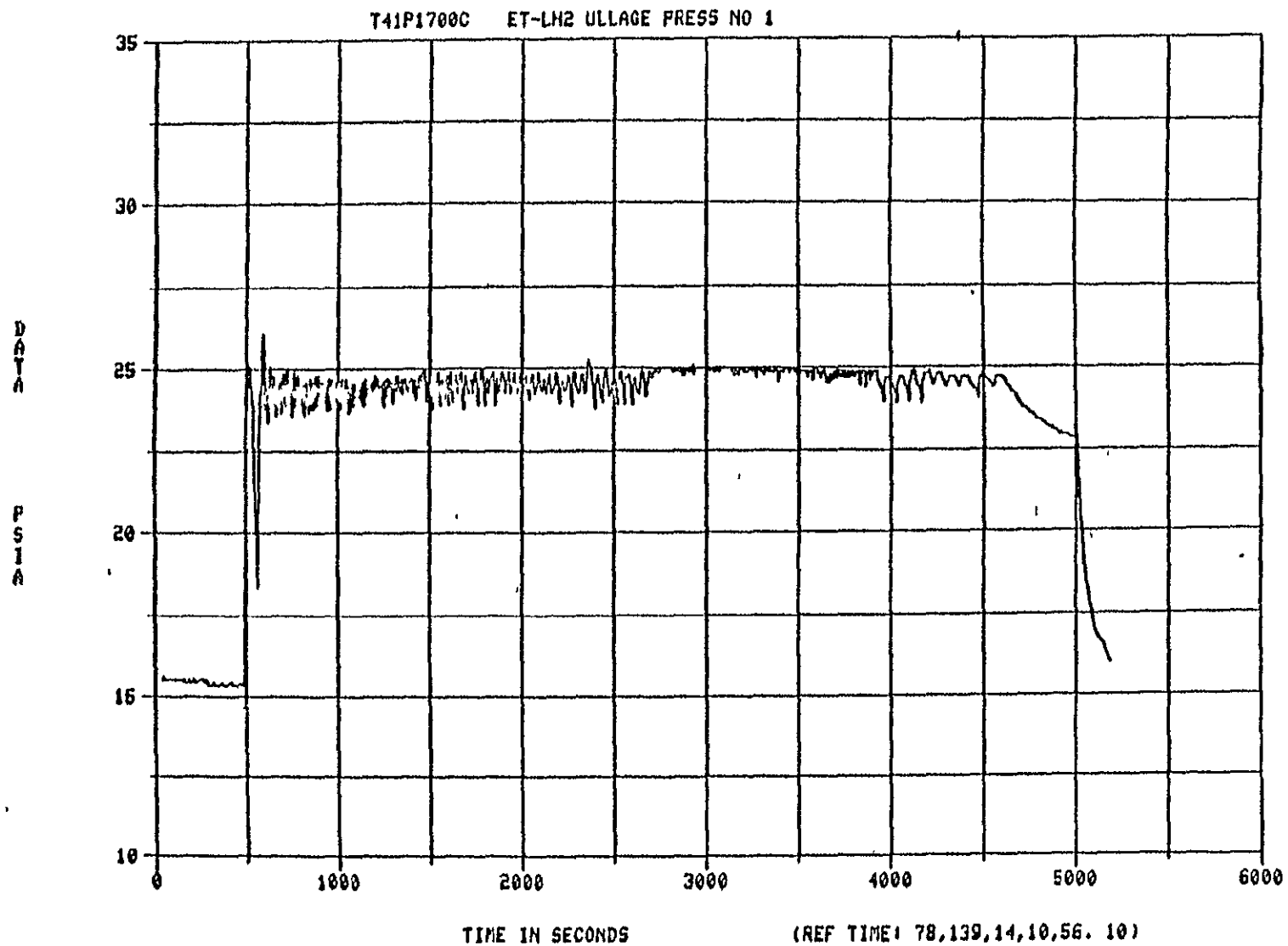
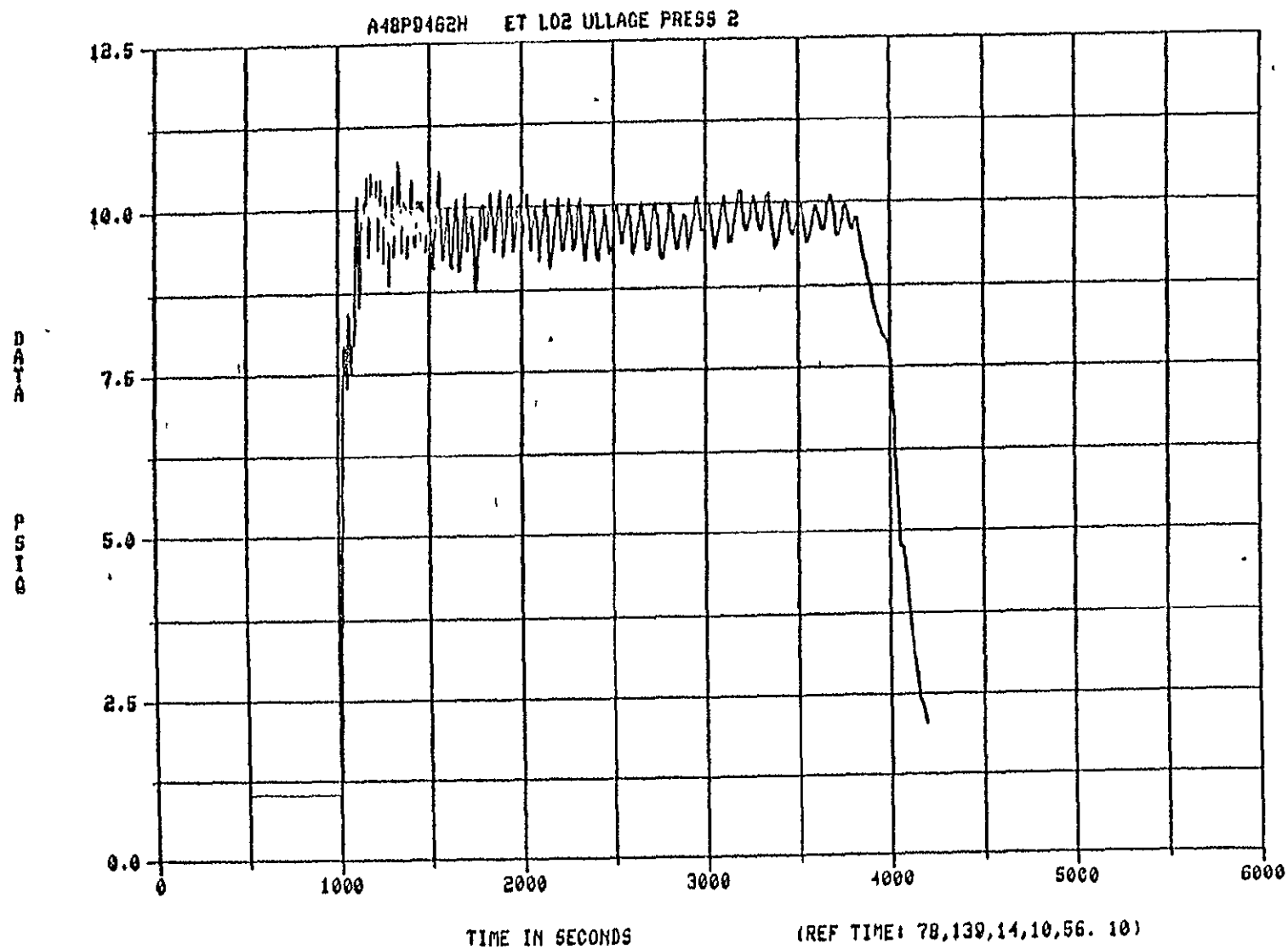


FIG. 4.1.1.1-18

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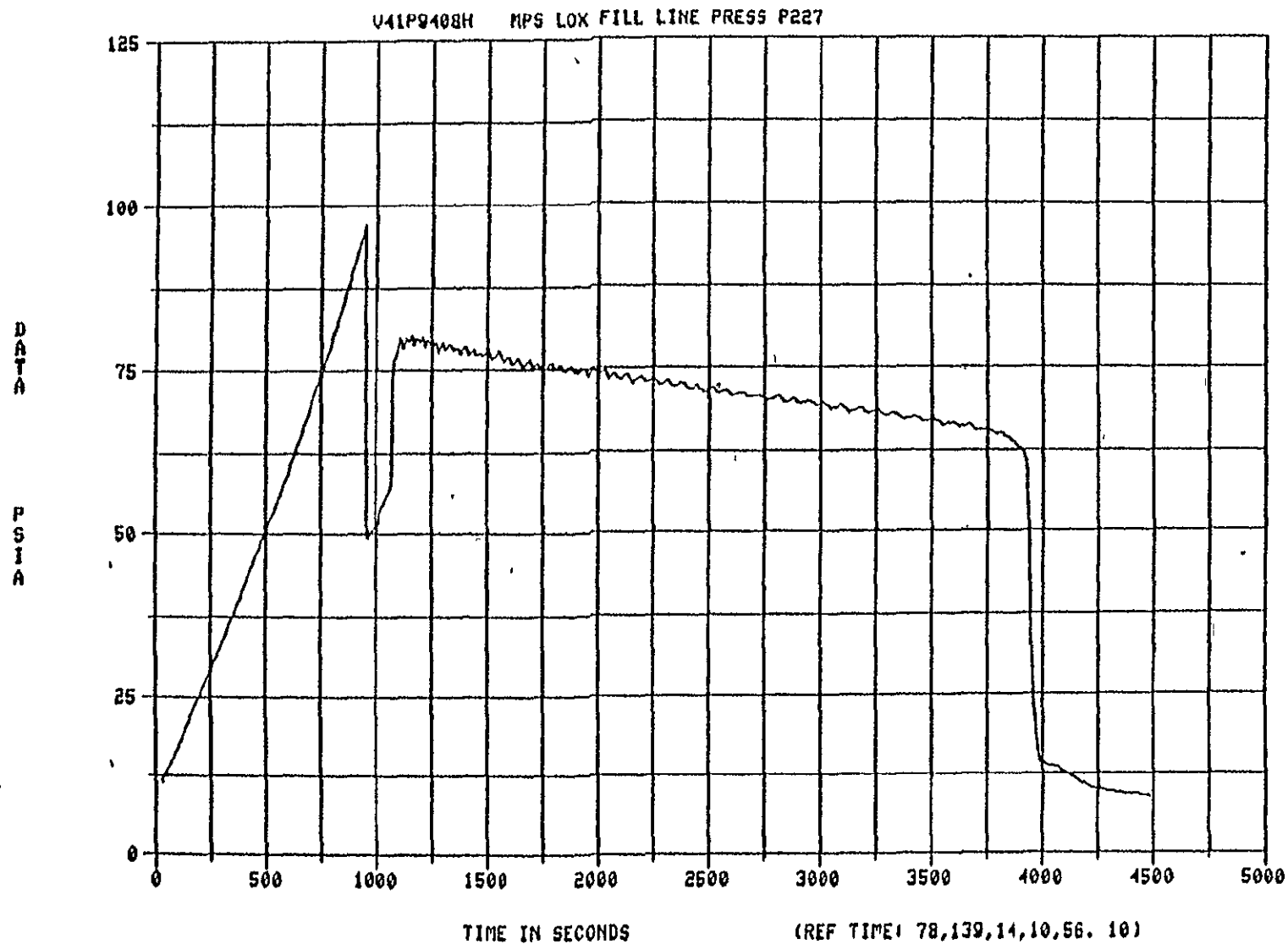
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FIG. 4.1.1.1-19



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FIG. 4.1.1.1-20

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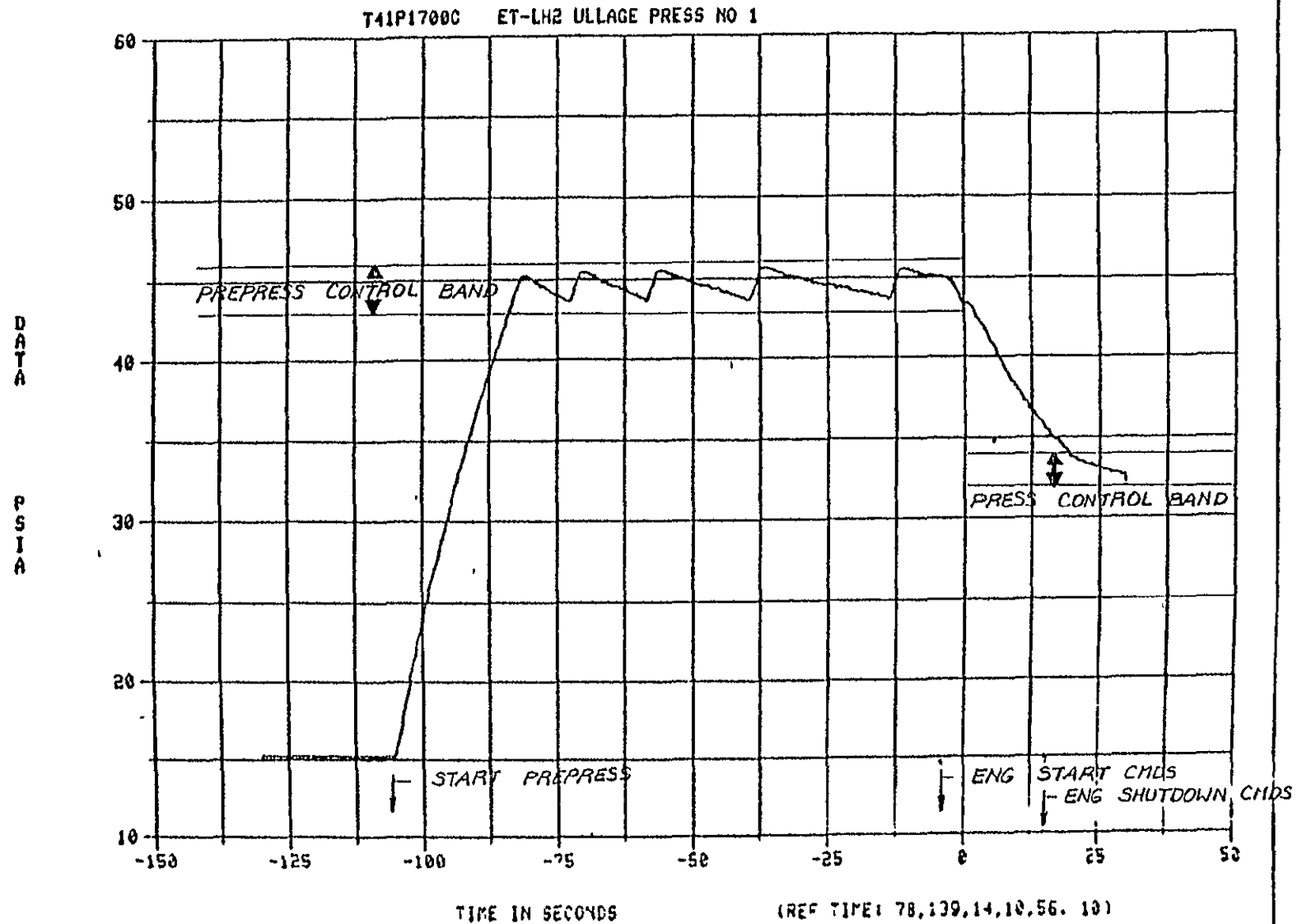


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4 1.1.2 Pressurization System. Pressurization system performance for the ET LH₂ and IO₂ tanks is presented in Figures 4 1.1.2-1 through -14. Included are tank ullage pressure histories, pressurant characteristics at the Orb/ET interface, ORB/GSE interface pressure, and ORB/SSME interface pressurant characteristics for which Engine No. 1 was selected as representative. Ullage pressures in both tanks were maintained within the prepress and pressurization control bands. Ullage pressure overshoot, which occurred during MPT-SF102, was solved by an orifice modification to the GSE helium supply valves. The LH₂ prepress control band was 43-46 psia for this test to avoid countdown recycling due to erroneous SSME transducer information. Base-line LH₂ prepress control band is 41-44 psia.

Orb/SSME interface pressurant characteristics were as expected during the firing. Orb/SSME interface CH₂ pressurant pressures and temperatures were reasonably similar for the three engines. CO₂ pressures ranged from a low of about 2300 psia for Engine No. 2 to a high of about 2640 psia for Engine No. 3. Orb/SSME interface temperatures ranged from 245°F for Engine No. 2 to 325°F for Engine No. 3 at engine cutoff command. The CO₂ pressurant temperature did not stabilize during the 15 second firing due to the slow response of the SSME heat exchangers, but the CO₂ temperature transient characteristic was evident in previous single engine tests. CH₂ pressurant temperature at the Orb/ET interface was below the ICD minimum for 70% power level, but is consistent with more recent engine data which indicates a different temperature vs. power level characteristic than that in the Orb/ET ICD. Pressurization duct pressures at the Orb/ET interface and ET orifice inlet were near the expected values, except for the IO₂ flow control valve, which cycled once during the start transient. The pressurization flow control valves did not cycle during the firing. The LH₂ flow control valves remained closed as the ullage pressure dropped predictably from the 43-46 psia prepress control band to the 32-34 psia mainstage pressurization control band. The IO₂ flow control valves remained open in order to supply pressurant to maintain 20-22 psig ullage pressure (34 7-36.7 psia at ground level). The orifices in the CO₂ flow control valves are sized to maintain 20-22 psig ullage pressure during flight.

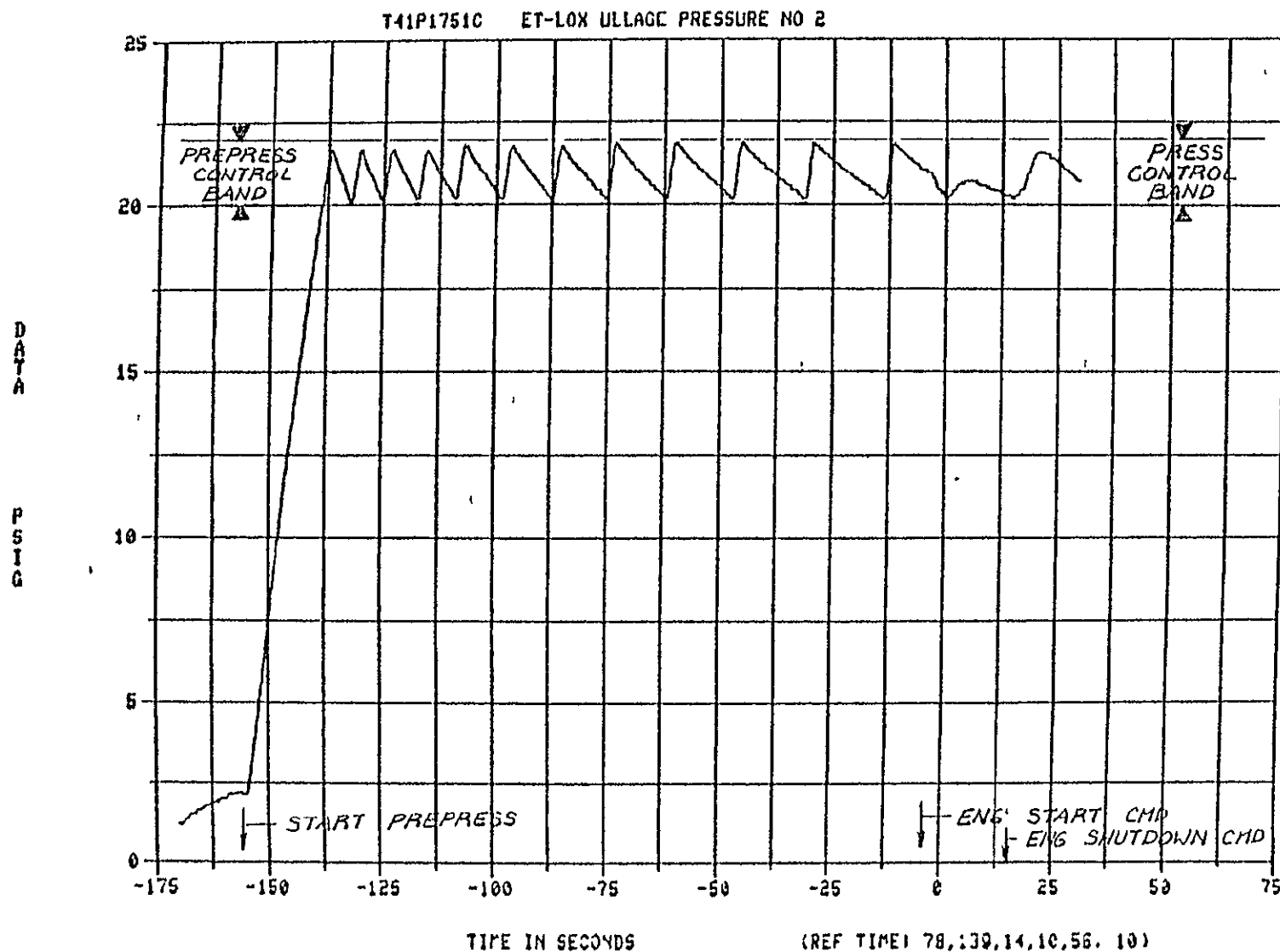
FIGURE 4.112-1



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FIGURE 4.112-2

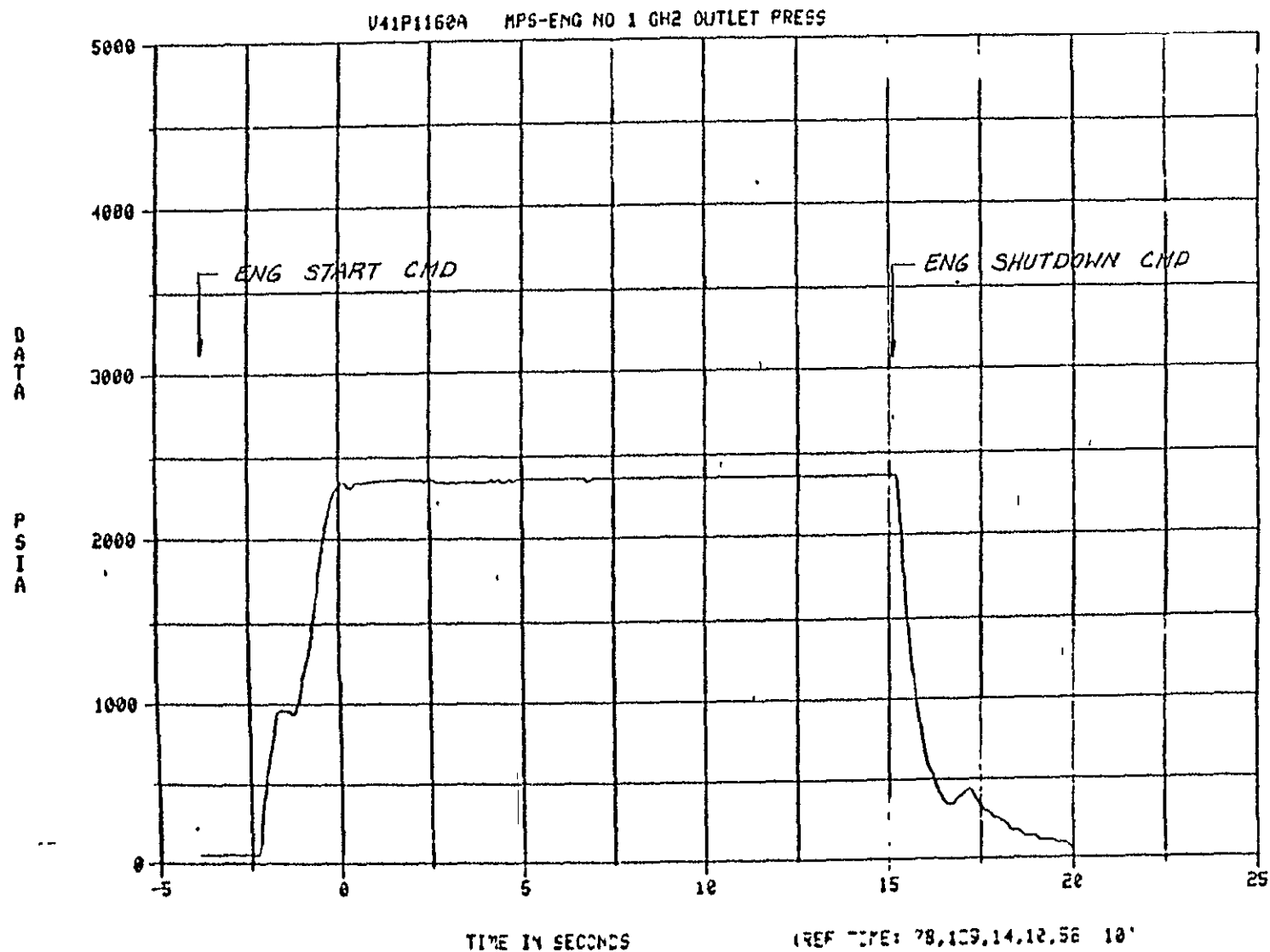


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FIGURE 4.11.2-3

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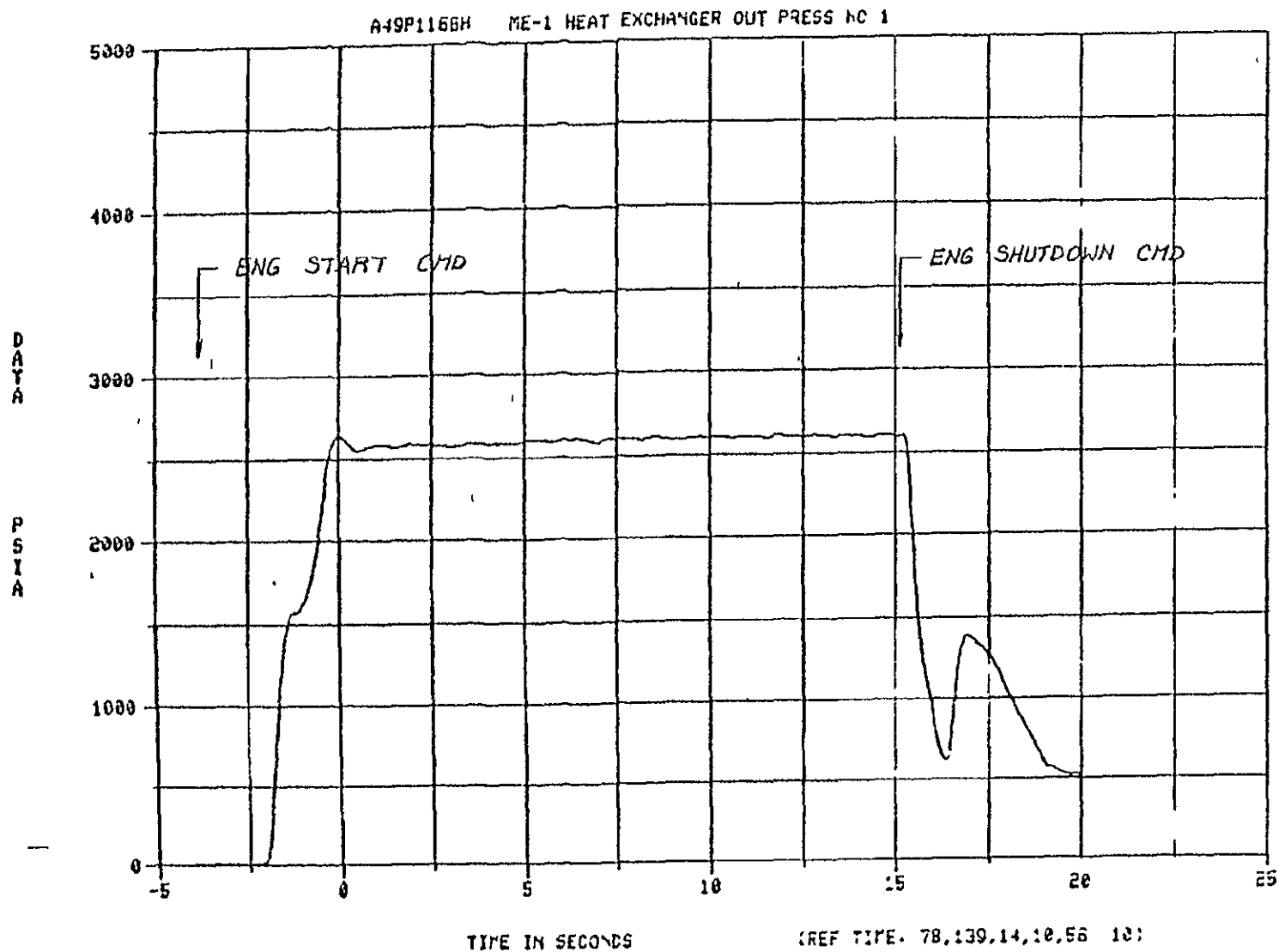
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FIGURE 4.1.12-4

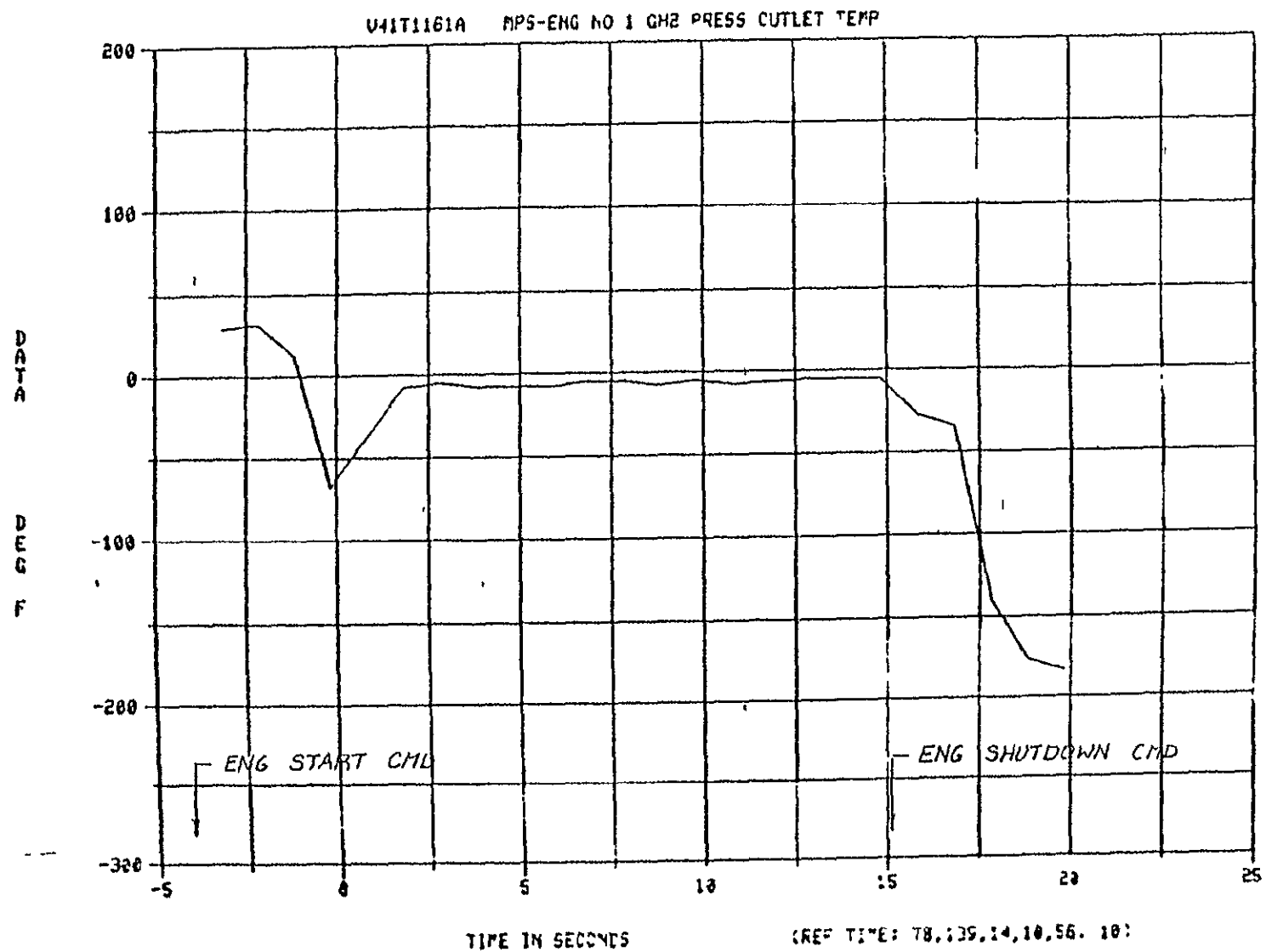


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FIGURE 4.11.2-5

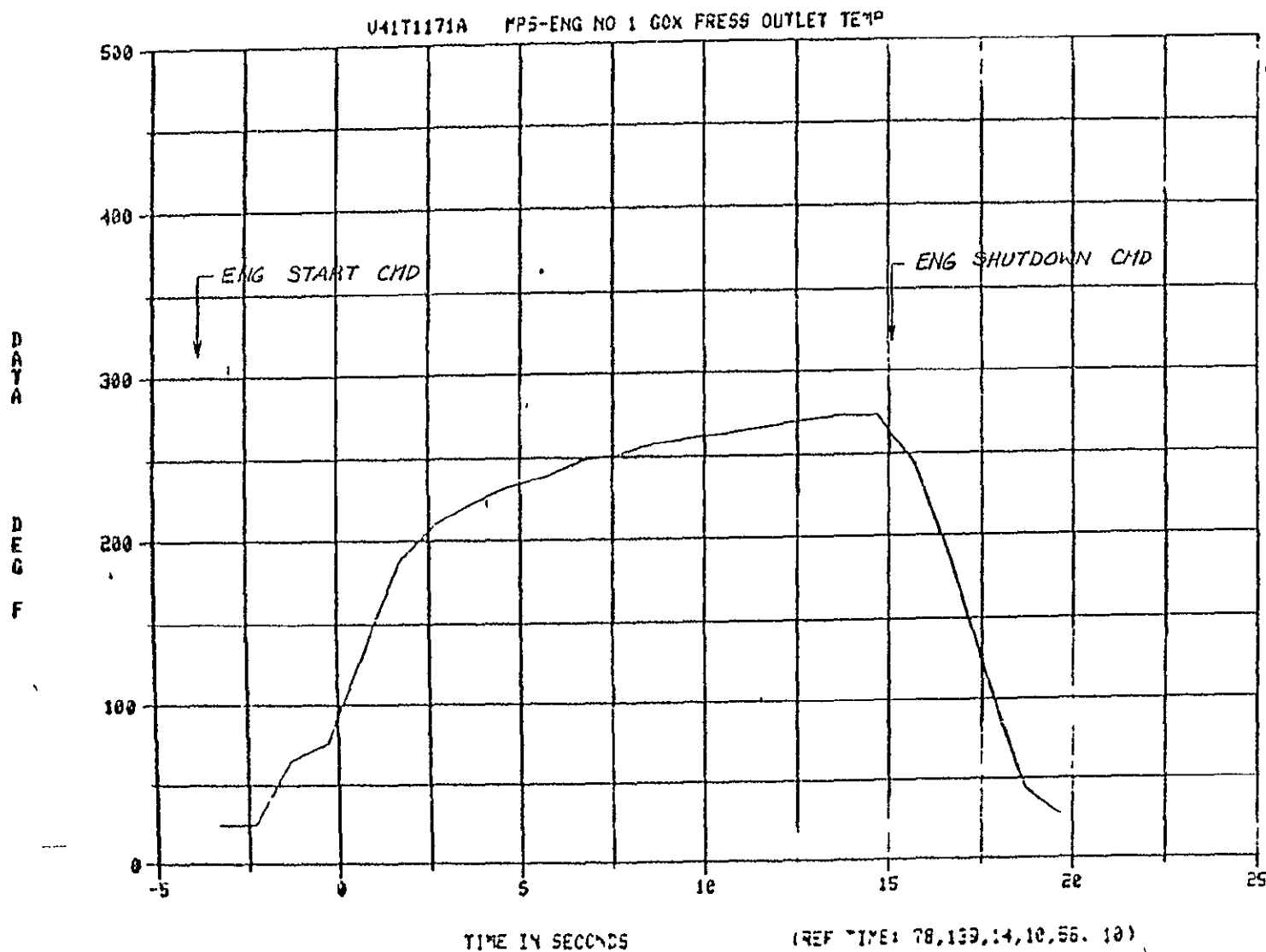


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FIGURE 4.1.1.2-6



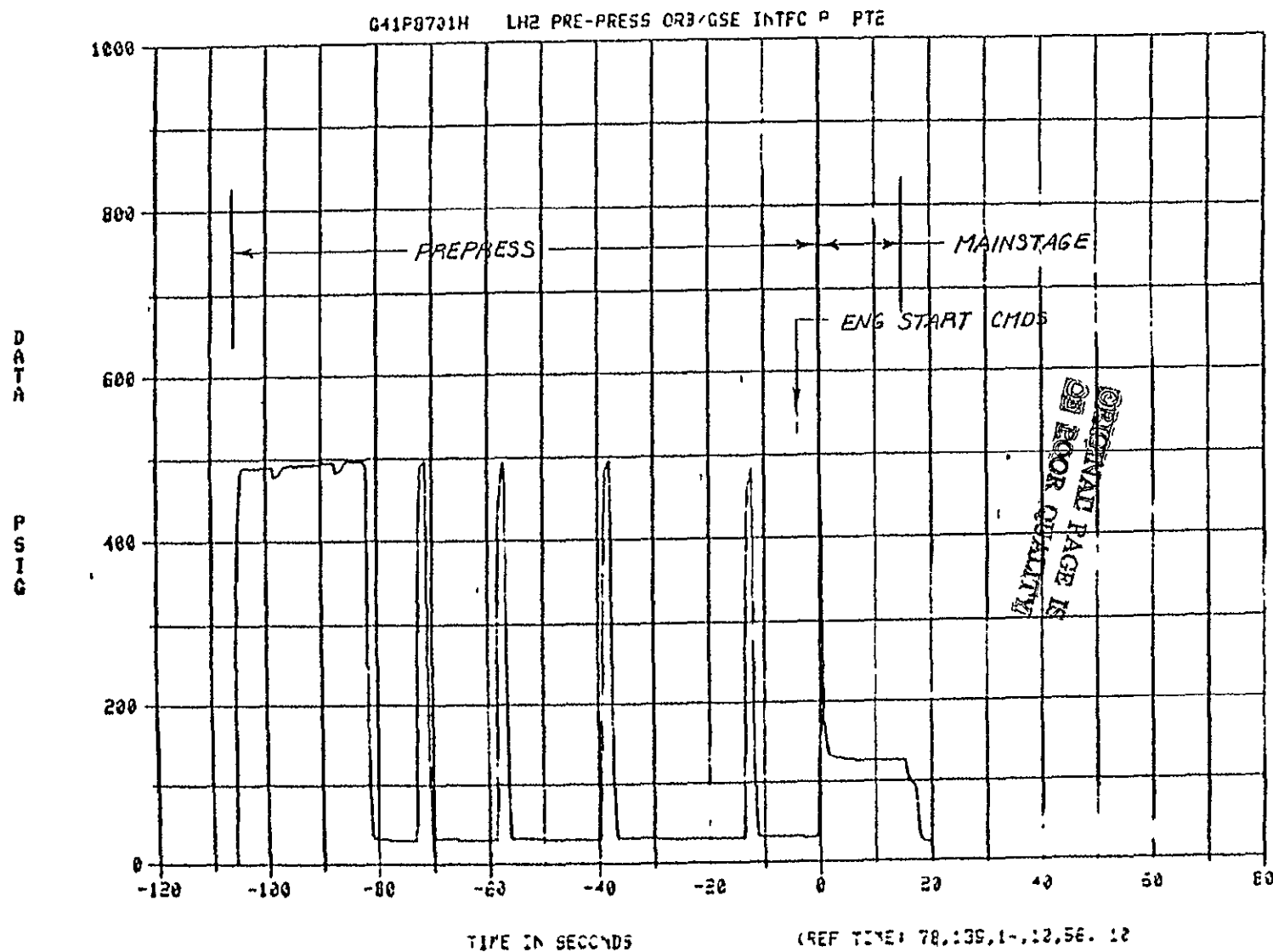
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FIGURE 4.112-7



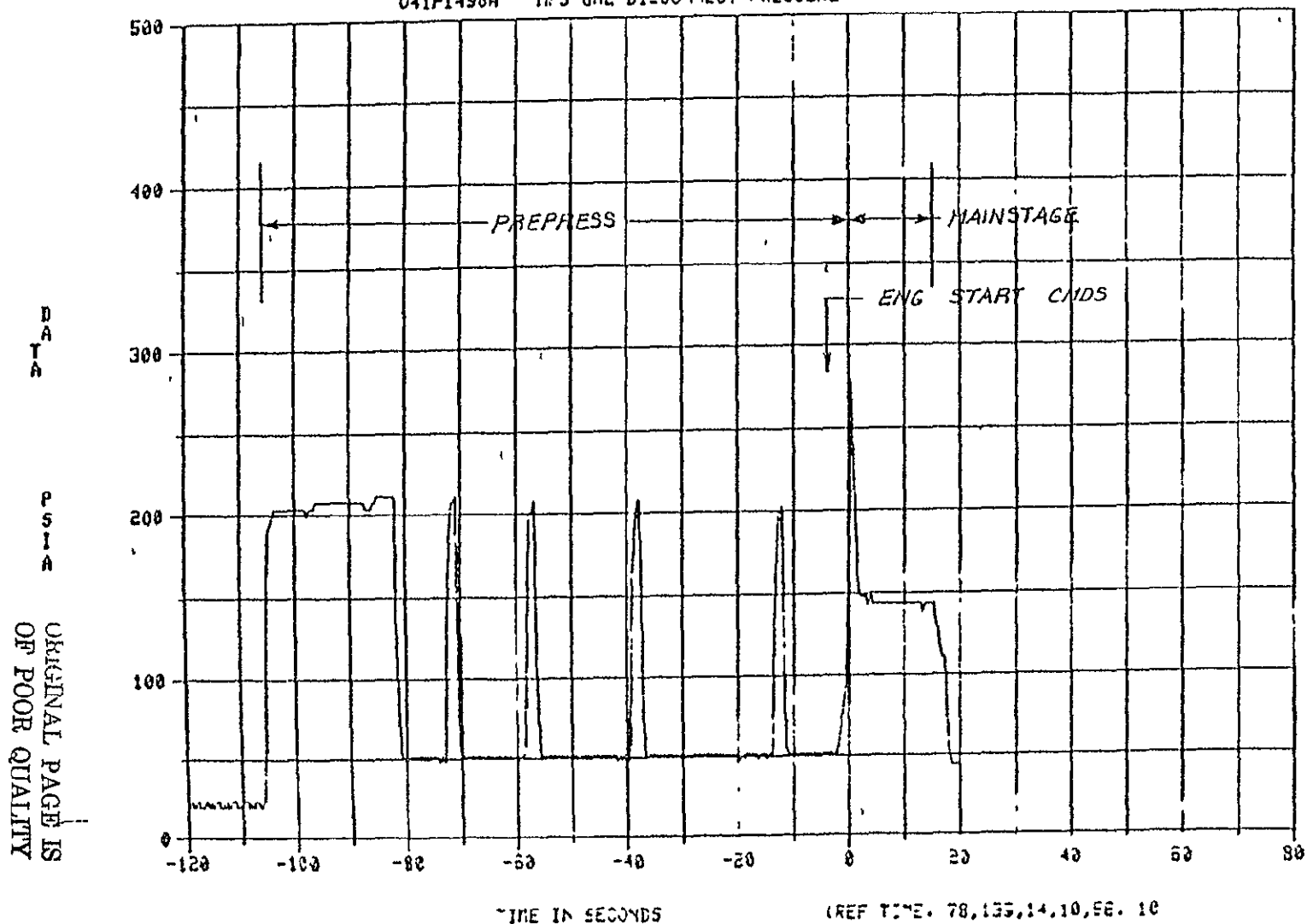
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FIGURE 4.112-8

U41P1490A MPS-Gm2 DISCONNECT PRESSURE



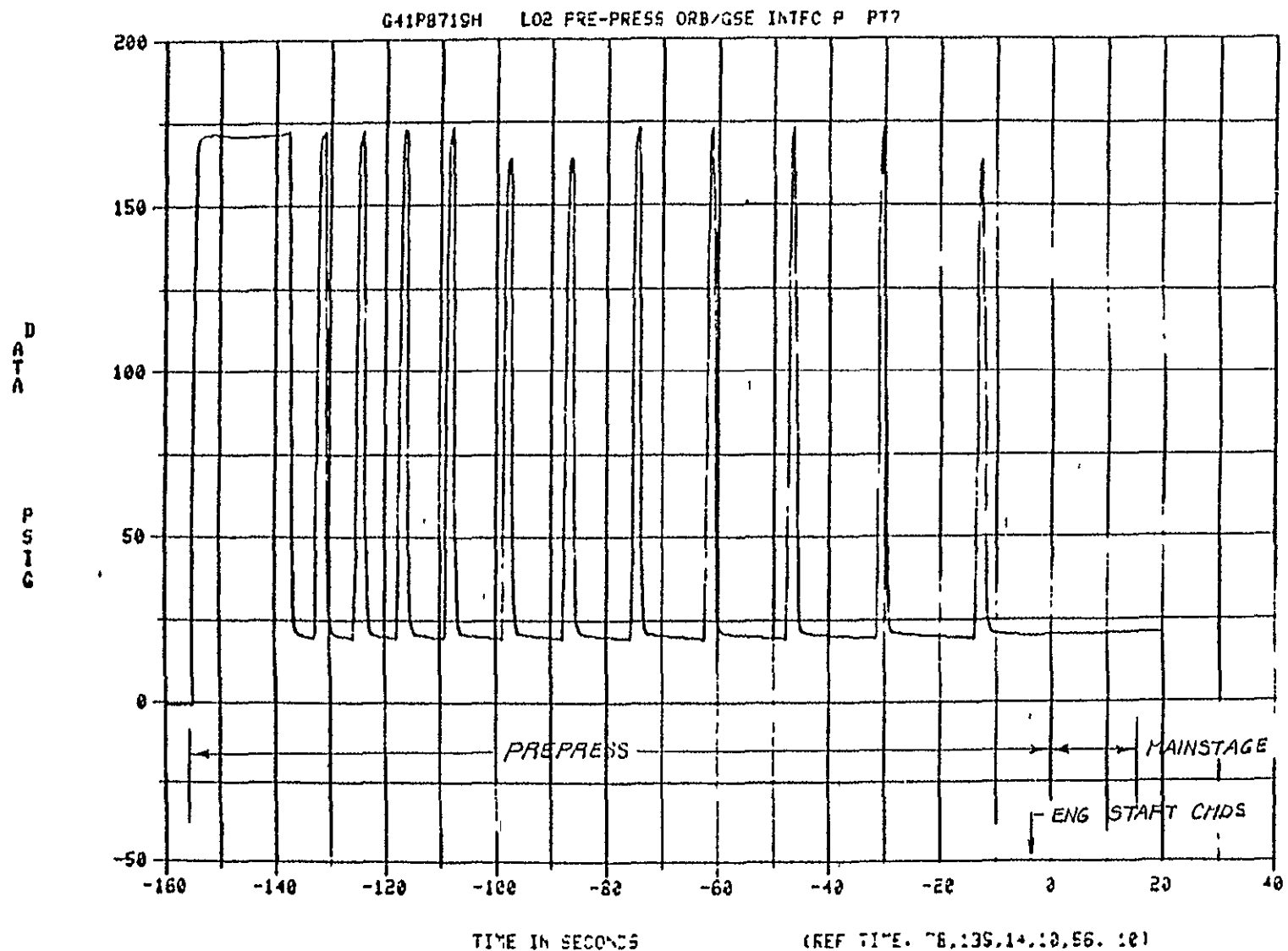
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FIGURE 4.112-9

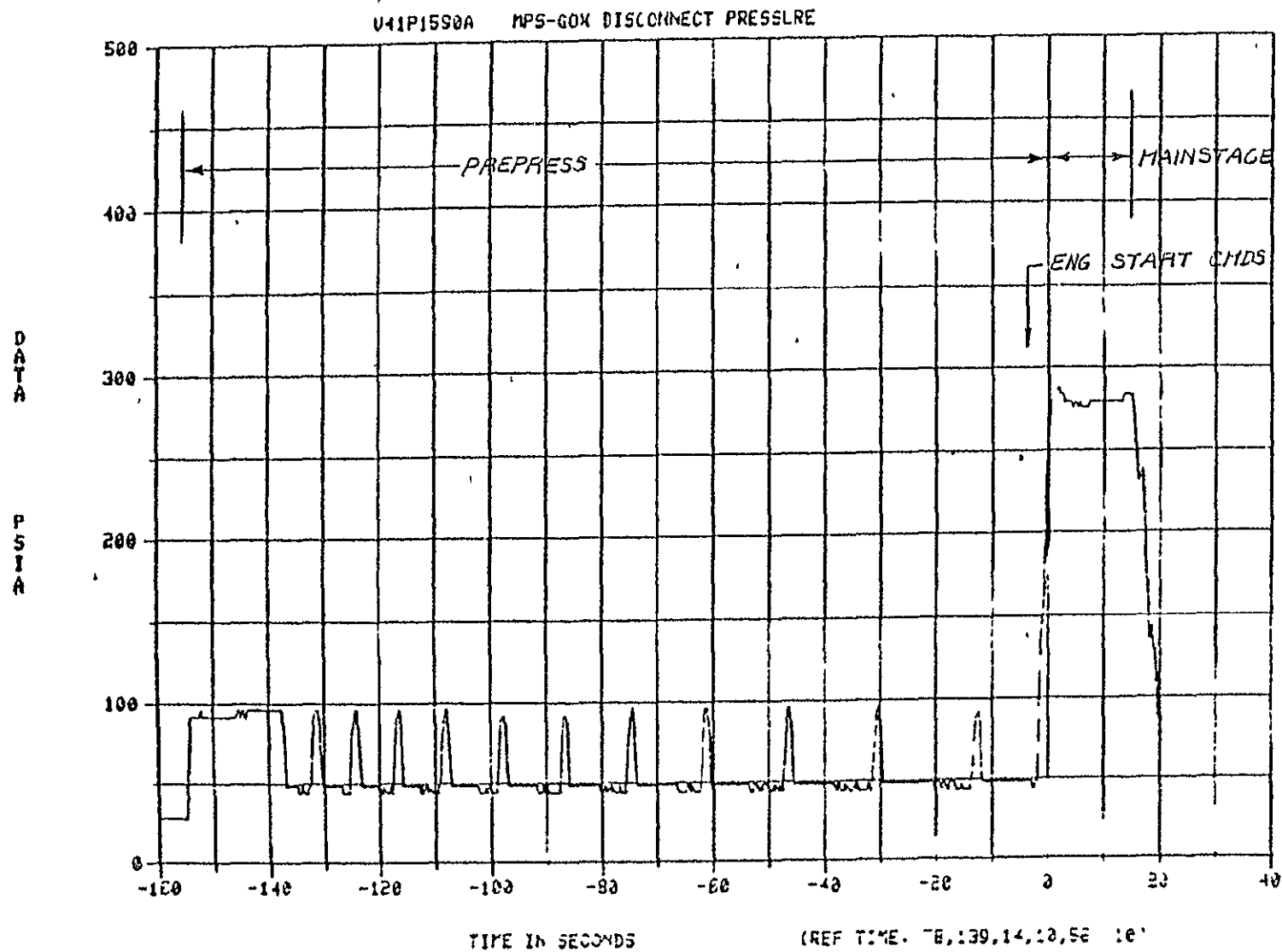


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FIGURE 4112 10

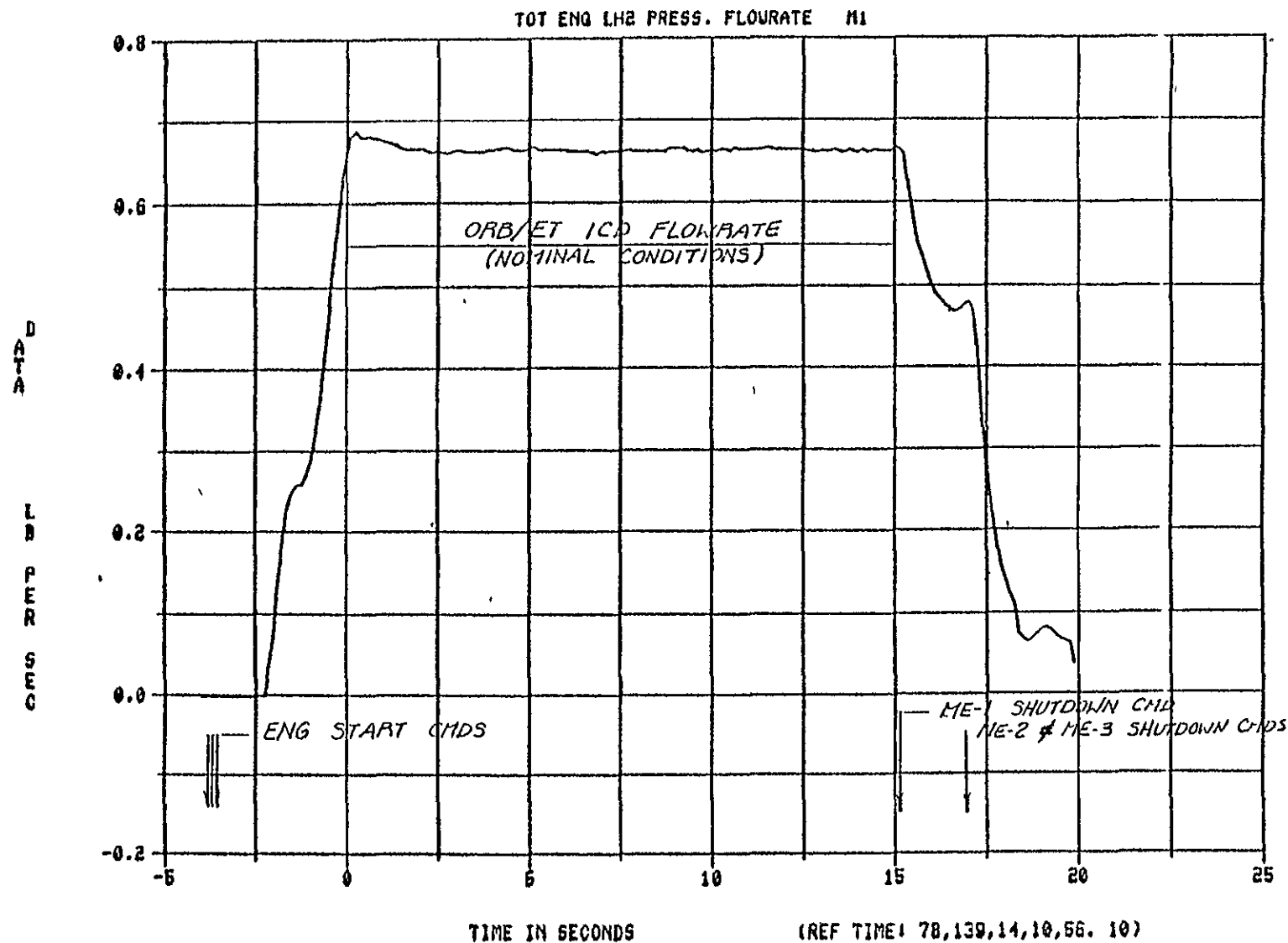


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FIGURE 4.112-11



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FIGURE 4112-12

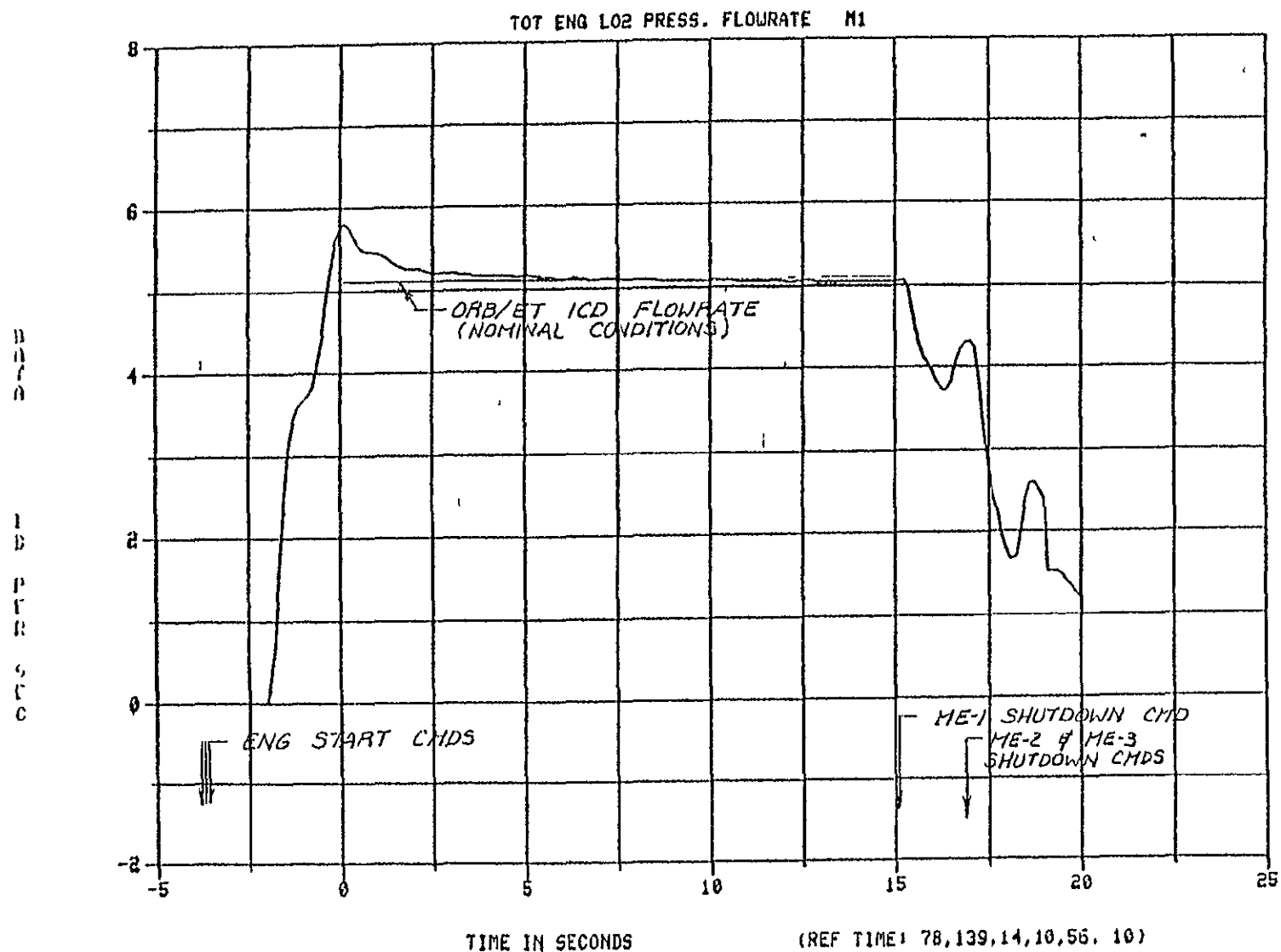
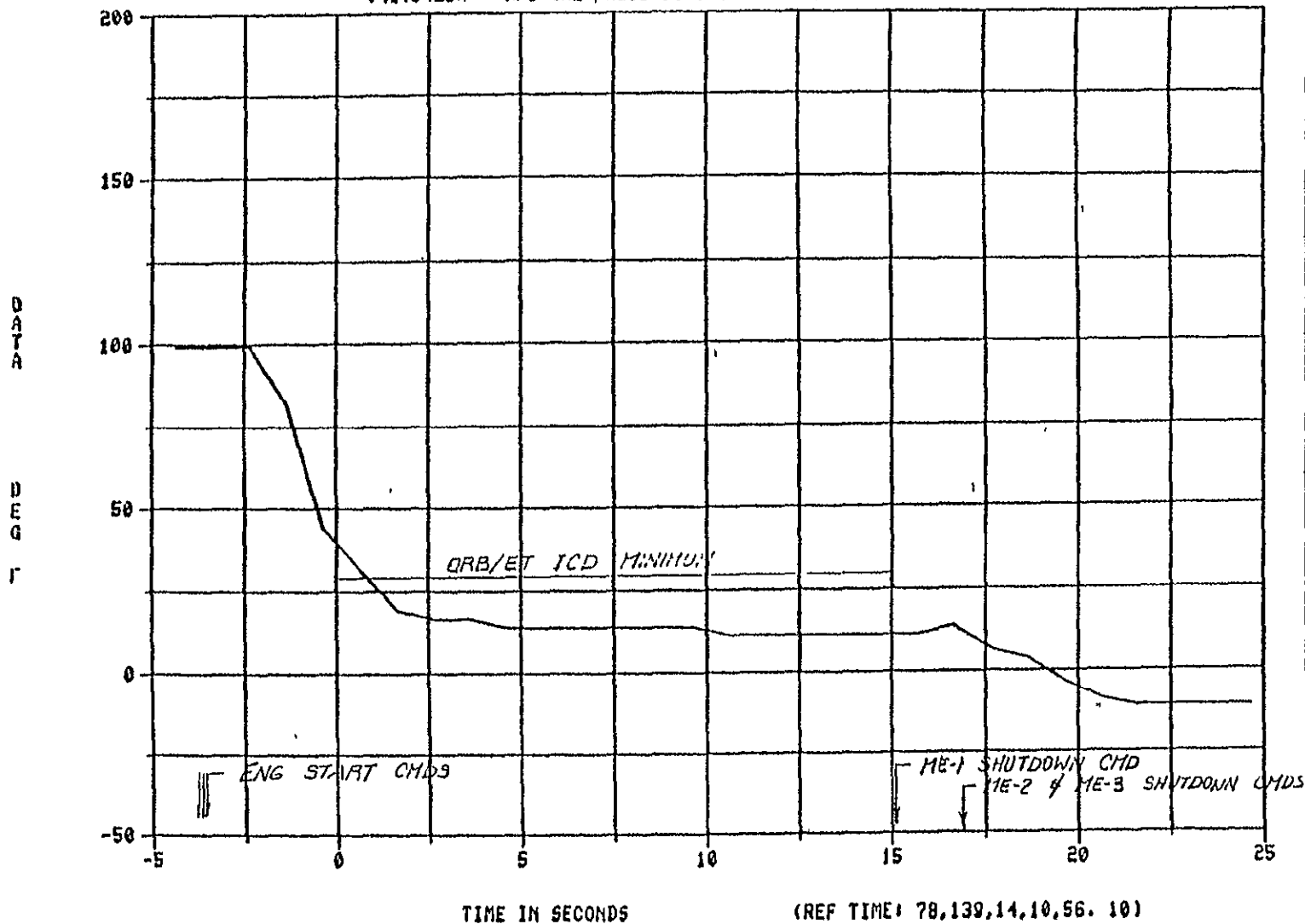


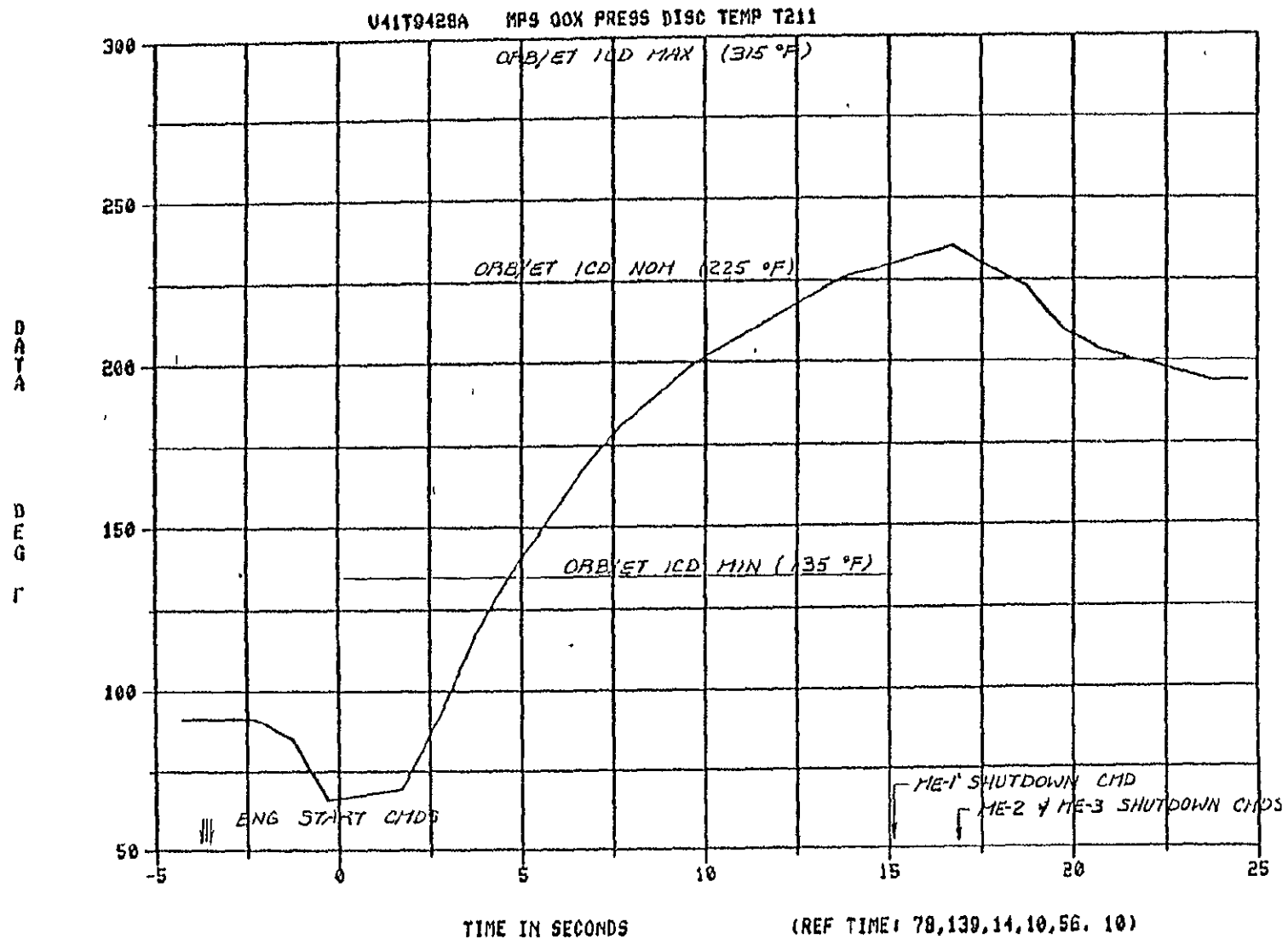
FIGURE 4112-13

V41T9429A MPS GH2 PRESS DISC TEMP T212



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FIGURE 4.1.2-14



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4.1.1.3 Preconditioning

4.1.1.3.1 LH2 Preconditioning (LH2 Recirculation, LH2 High Point Bleed)

For MPT-S2-001 a number of physical and procedural changes had been incorporated to eliminate previously-identified problems and to better aid in verification of system performance. One of the major procedural changes was to turn the recirc pumps on prior to fast fill termination. For this test the pumps were turned on at the 60% level. As predicted, stable pump operation was obtained, as seen on Figure 4.1.1.3.1-1a (-18,870 sec to -18,380 sec).

However, shortly after fast fill termination the pumps cavitated. Examination of the available data plus verbal information from cognizant personnel has established that the incident was the result of design problems with the facility rather than an inherent deficiency of the LH2 preconditioning system.

During fast fill the main fill valve (MV101) and the topping/replenish valve (LCV105) were open and the slow fill valve (FCV107) was closed; flow entered the orbiter system through the inboard fill and drain valve (PVL2). Refer to Figure 4.1.1.1-1 for valve locations. As noted earlier, the recirc pumps were turned on during fast fill and operated stably. At fast fill termination the topping mode is activated by closing MV101. The desired (ICD) topping rate is 9-11 lb/sec (920-1120 gpm). Inasmuch as the range of the topping flowmeter (FE105) is only 0-300 gpm it was assumed that a nominal topping rate of 1000 gpm could not be attained through LCV105, consequently FCV107 was opened approximately 50% to help assure that an adequate topping rate was attained. Prior experience had shown that, with the facility valves in the noted positions, high Orb/GSE I/F pressures result, thereby causing relief valve (RV1) to open (33 psig cracking pressure). To avoid opening the relief valve, MV104 was opened to trim the I/F pressure by dumping fluid into the facility vent system. The flow from MV104 was dumped into a 4" facility line also used by the LH2 high point bleed system and the RTLS dump system. Pressures on the order of 10 psig were developed in the facility vent line, as shown in Figure 4.1.1.3.1-2 (T-18,350 sec). Inasmuch as the pressure in the orbiter 17" line is on the order of 3.5 psig (2.5 psi hydrostatic head plus 1.0 psig ullage pressure), vapor flowed into the 17" line through the high point bleed line. The inflow of vapor displaced liquid in the 17" line and resulted in recirc pump cavitation.



An additional problem has been noted relative to the topping rate. The topping flow enters the orbiter system through the replenish valve (PVL3), after which it merges with the recirc return flow going to the ET. High topping flow rates can cause high pressure drops in the recirc return line, thereby causing a reduction in recirc pump flow. In Figure 4.1.1.3.1-1a (T-18,380 sec) it is seen that the recirc pump delta P did go high during topping, indicative of reduced flowrate. The calculated flow rate during the topping period is 0.49 lb/sec.

The calculated pressure drop through the orbiter replenish system is 9.0 psi at a topping rate of 11.0 lb/sec. With 2.8 psi hydrostatic head at the Orb/GSE I/F plus 1.0 psig ET ullage pressure the expected max interface pressure would be 12.8 psig. On Figure 4.1.1.3.1-3 it is seen that the Orb/GSE I/F pressure was approximately 40 psig during the topping period (T-18,380 sec) resulting in a orbiter system delta P of 36.2 psi (40-2.8-1.0 = 36.2 psi). The estimated topping flow is 22.06 lb/sec ($11 \sqrt{\frac{36.2}{9.0}} = 22.06$ lb/sec), or 2250 gpm. Although the high

topping rate is not considered to be the principal cause of the recirculation pump cavitation, it was a contributing factor inasmuch as the reduced recirc pump flow tends to cause more of the system heat load to go to evaporation rather than to bulk heating of the liquid. It is to be emphasized, however, that recirc pump cavitation could be caused by excess back pressure in the recirc return line, and pump cavitation might have been encountered even if the high facility vent line pressure had not been encountered concurrently.

If there is any "culprit" in the pump cavitation event, it may be considered to be the lack of facility flowmeter to measure topping flowrate. The absence of a suitable flowmeter caused the test conductor to operate "blind", thereby resulting in the sequence of events that resulted in pump cavitation.

To help avoid recurrence of recirc pump cavitation due to high pressure in the facility vent line, the NSTL facility is being modified to add a new section of 3" diameter line to duct the LH2 high point bleed flow to the 18" vent line independent of flow from valves TCV106 and MV104. It is recommended that a suitable topping flowmeter be incorporated into the facility as soon as possible. Until a flowmeter is available, the Orb/GSE I/F pressure (G41P8704H) may be used as a guide. For the ICD topping range of 9-11 lb/sec (920-1120 gpm) the anticipated interface pressure is 9.8 to 12.8 psig. It is recommended that during topping the interface pressure be maintained in the range of 10-13 psig (replenish valve PVL3 open, and inboard F&D valve PVL2 closed)



The topping flow should be attained initially with LCV105 alone. Subsequent adjustments to the position of LCV105 and/or the partial opening of FCV107 should be made on the basis of the observed I/F pressure.

After a down period to fix a facility leak the vapor in the orbiter 17" line was expelled by a brief drainback period, and the recirc pumps were reactivated. Stable operation was attained as shown by the pump delta P curve on Figure 4.1.1.3-1b. At T-10,150 sec replenish flow was initiated. The recirc pumps continued to operate stably after replenish initiation but the recirc flow dropped slightly in response to the added back pressure produced by the replenish flow. With stable recirc pump operation the engine inlet temperature requirements were easily met. Figure 4.1.1.3.1-4 shows the engine inlet conditions obtained from MPT-S2-001. The values were very close to predicted and the prestart conditions were well within the engine prestart box. It is noted that for this test the ullage pressure was set at 43-46 psia instead of the baseline range of 41-43 psia. The higher pressures were used to compensate for errors in the instrumentation for the "engine ready" signal, thereby helping to avoid an unnecessary firing inhibit signal.

On the basis of data from MPT-S2-001 it is concluded that the LH2 preconditioning system is satisfactory. Observed anomalies are explained by problems originating in the facility. Resolution of the physical and procedural problems in the facility should prevent a recurrence of the recirc pump cavitation problem.



4.1.1.3.2 IO₂ Preconditioning (IO₂ Overboard Bleed, Antieyser) For

MPT-S2-001 the IO₂ preconditioning system worked satisfactorily. The engine inlet prestart temperatures were within the start box, and the HPOP discharge was subcooled. This information is shown in Figure 4.1.1.3.2-1. The underlined measurements in the Table of Figure 4.1.1.3.2-1 are the ones used for the figure. Although the pressure levels are clustered toward the lower pressure side of the prestart box, verbal information from test observers indicates that the pressures actually were closer to the predicted values

The only problem was procedural. For this test the bleed flow had been adjusted to 80 gpm, based on verbal information. Although the desired range is 69.5 to 75.9 gpm (11-12 lb/sec), the 80 gpm is closer to the desired range than had been obtained in previous tests. However, at T-480 sec. the bleed flow was inexplicably increased to approximately 105 gpm. Figure 4.1.1.3.2-2 shows the Orb/GSE bleed I/F pressure during autosequence

The only effect of the anomaly was to degrade evaluation of the baseline system. For future tests it is recommended that the bleed flow control valve (FCV112) be preadjusted to a bleed rate of 70-75 gpm with 100% load and vented ET; readjustment should be made only if the desired rate is not attained at the 100% level.

For this test the auxiliary helium bubbling system was implemented for the antieyser line. Inasmuch as the helium flow is controlled by an orifice in the ET system, there was no apparent change in antieyser system operation from previous tests. The estimated Orb/ET I/F temperature was -295.5°F during autosequence as opposed to the maximum allowable temperature of -291.7°F. As in previous tests, there was no temperature spike in the engine inlet temperature during autosequence-drain-oack.

Based on data from MPT-S2-001 and previous tests it is concluded that the IO₂ preconditioning system is satisfactory. Pre-setting the bleed control valve and avoiding readjustments during a test will aid in a more complete verification of baseline system performance.

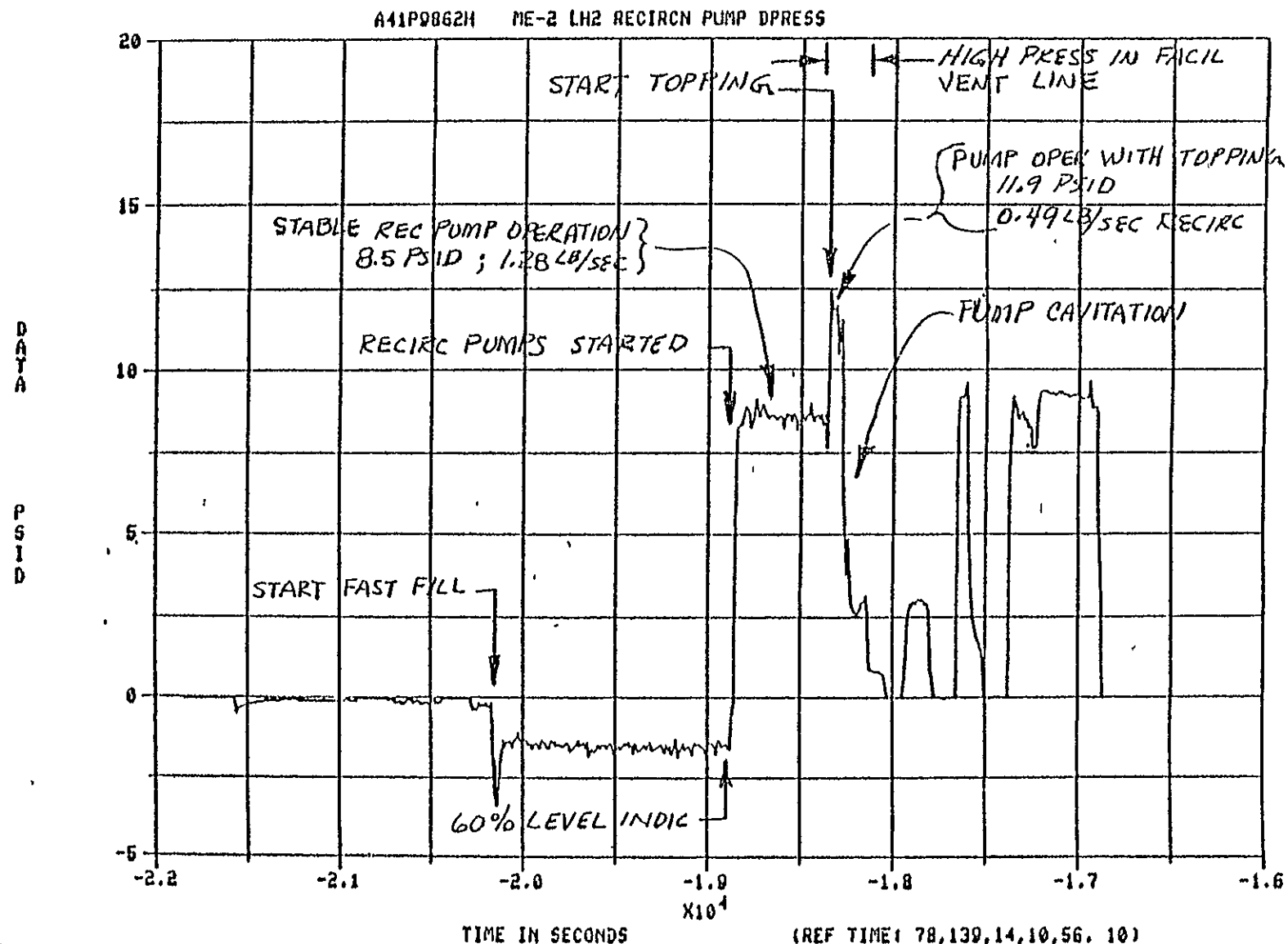
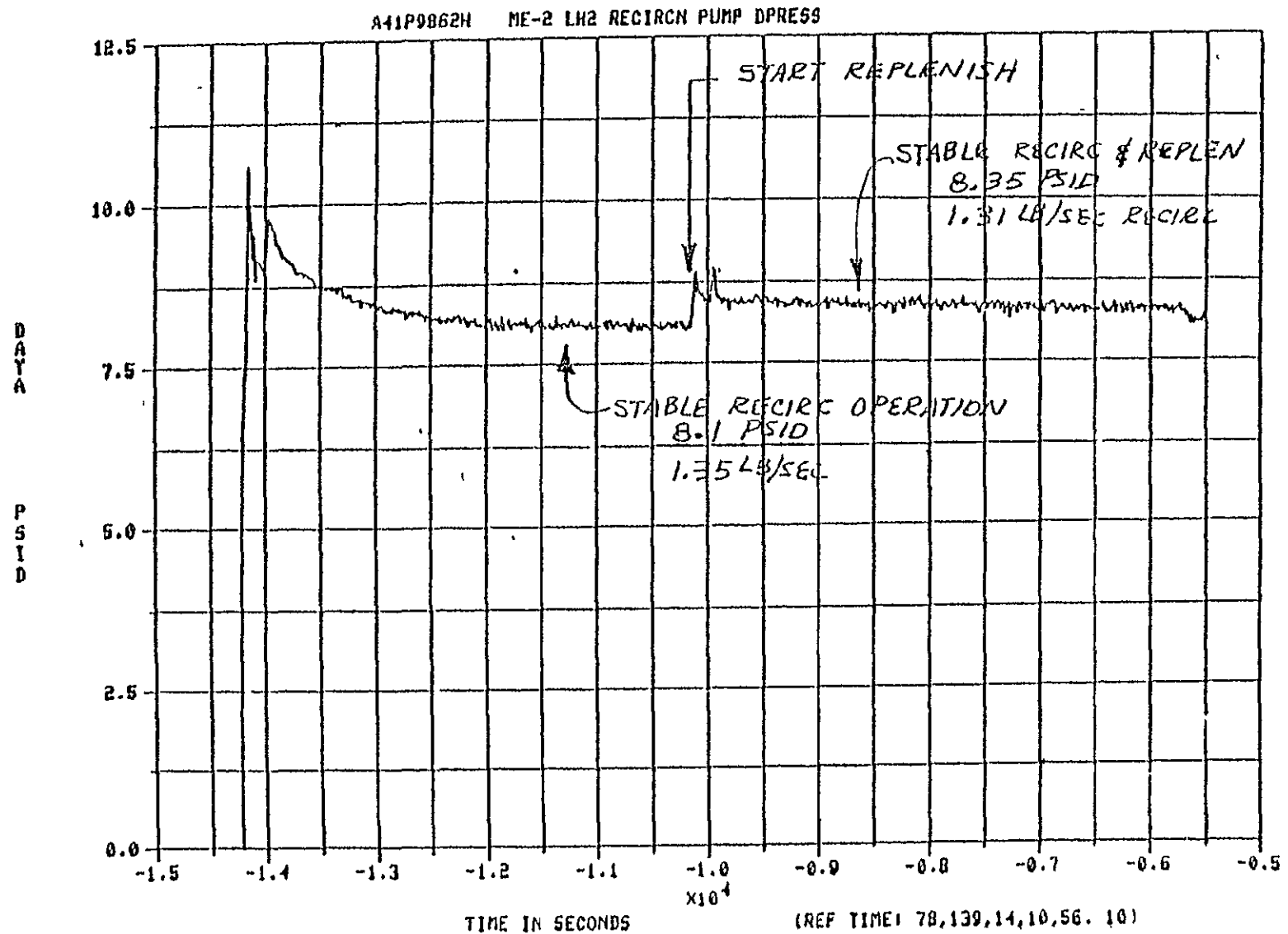


FIGURE 4.1.1.3.1-1b

TEST NUMBER MP15F2
TEST DATE MAY 10, 1971



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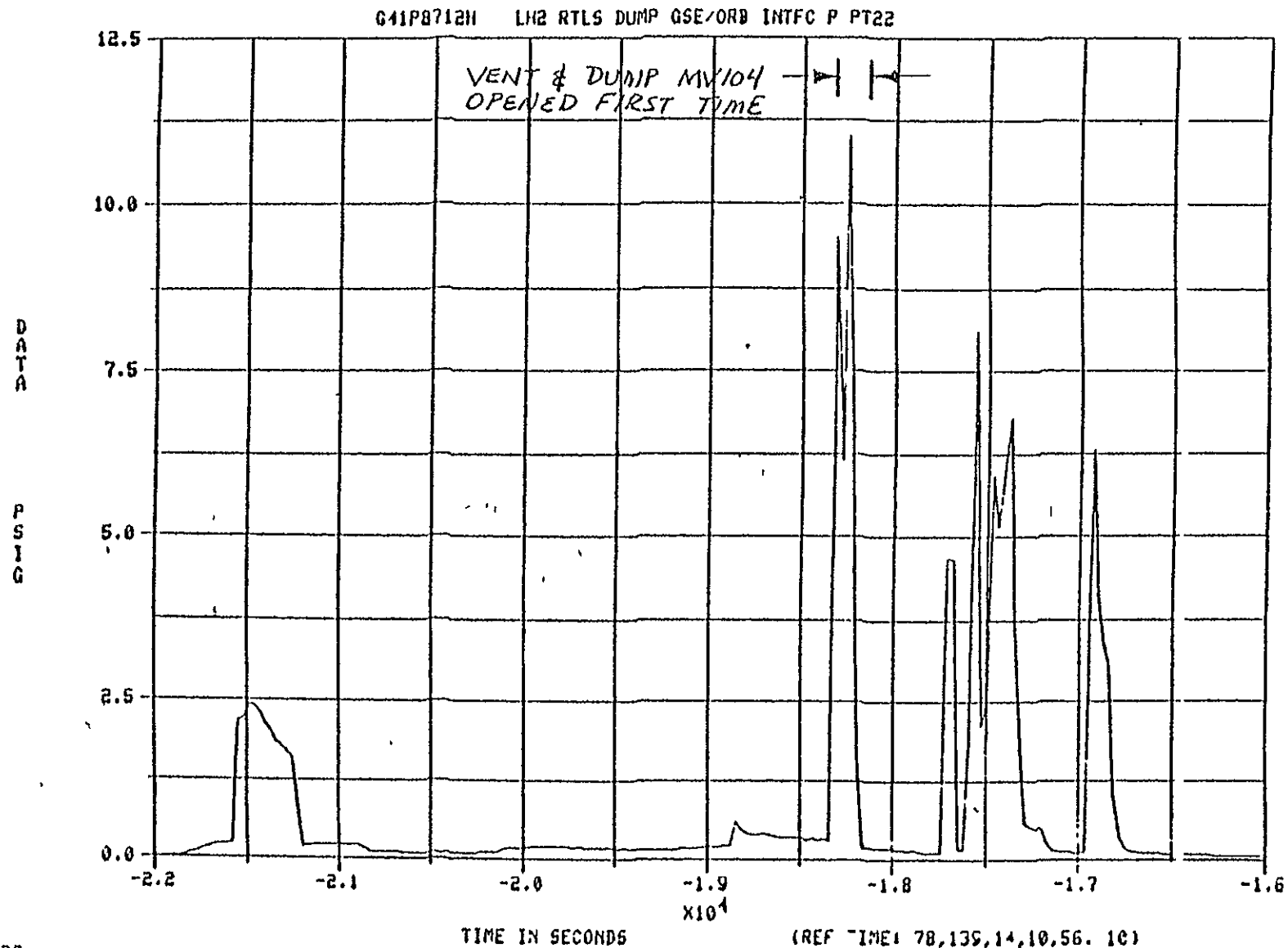


FIGURE 4.1.1.3.2-1

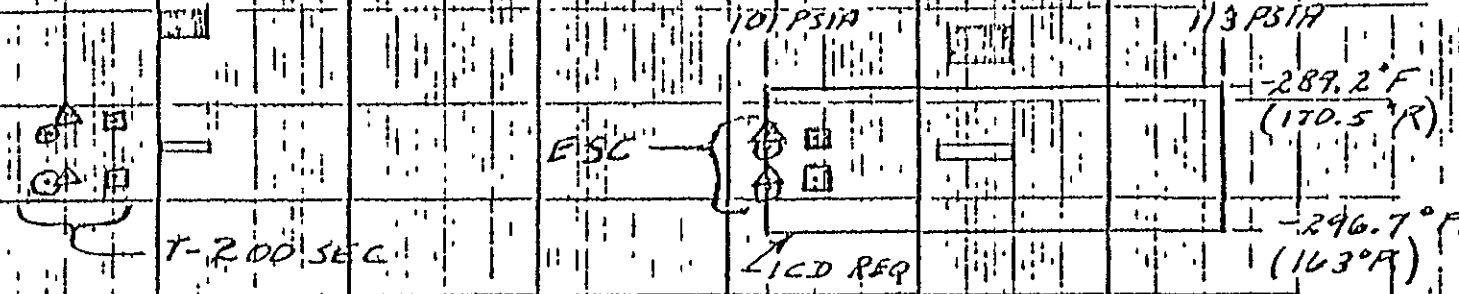
LO2 BLEED SYST PERFORMANCE - MPTA

SSME INLET
HPOP DISCHARGE

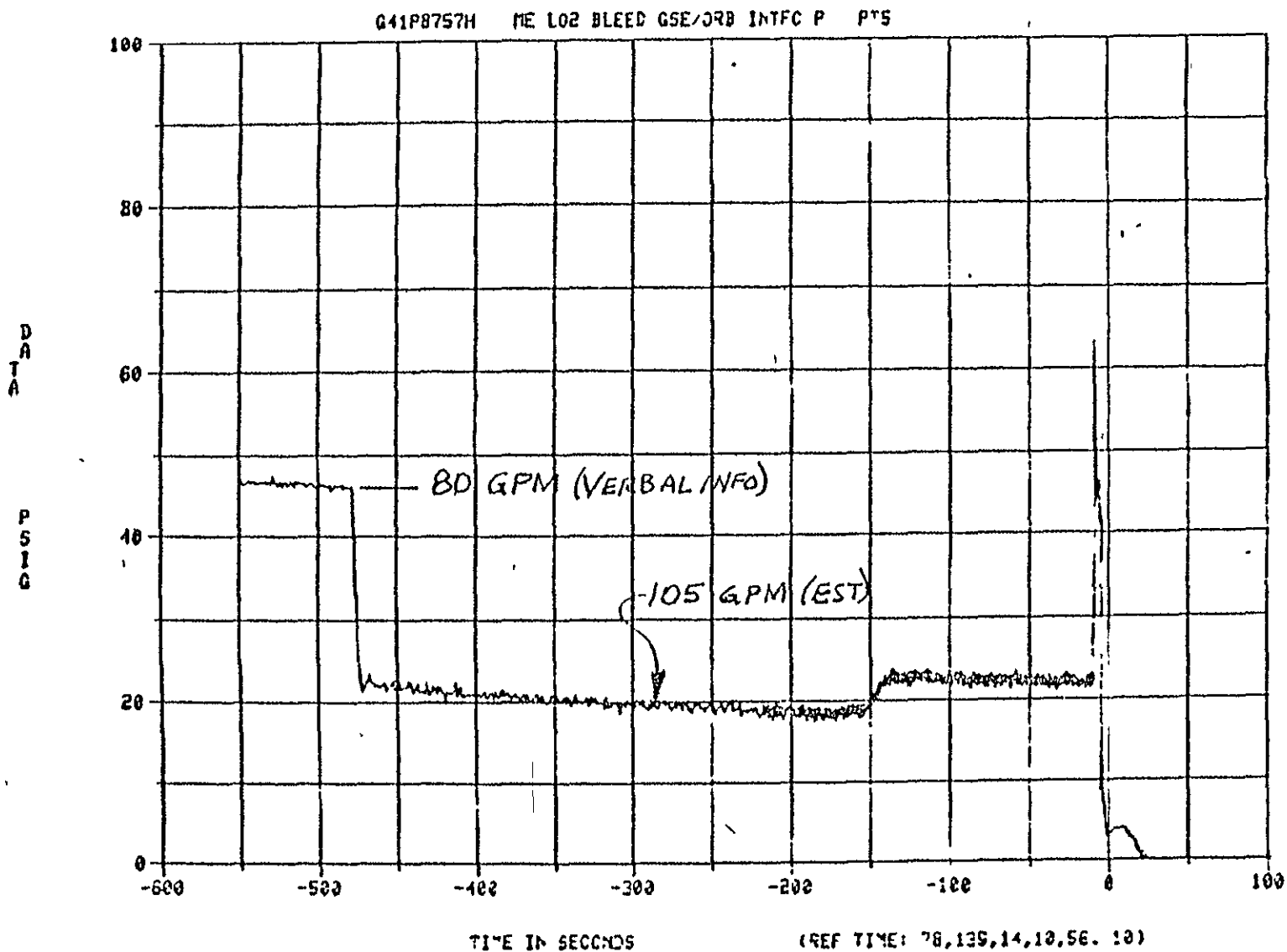
MPT + S2-001

SATURATION TEMP

	SSME INLET (PRED)	HPOP DISCH (PRED)	
	TEMP	PRESS	TEMP
OE1	V4IT1131C (S) V4IT1131H (F4GB)	V4IP1130C (S) V4IP1130H (F4GB)	E4IT1020B (S) E4IT1020D (T60)
E2	V4IT1231C (S) V4IT1231H (F4GB)	V4IP1230C (S) V4IP1230H (F4GB)	E4IT2020B (S) E4IT2020D (T60)
E3	V4IT1331C (S) V4IT1331H (F4GB)	V4IP1330C (S) V4IP1330H (F4GB)	E4IT3020B (S) E4IT3020D (T60)



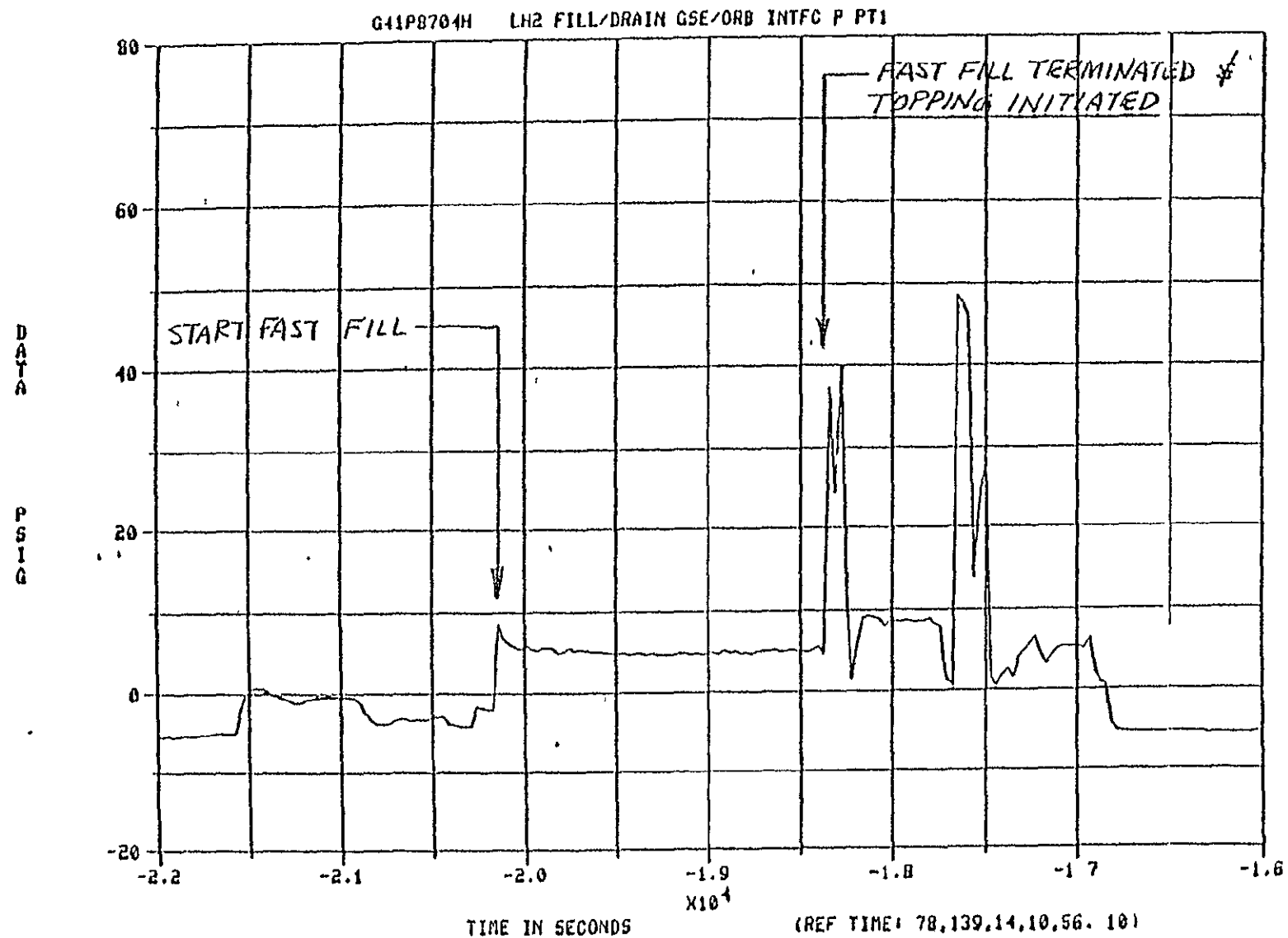
ENGINE INLET PRESSURE (PSIA)



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FIGURE 4.1.1.3.1-3

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TEST DATE M: Y 19, 1978



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FIGURE 4.1.1.3.1-4
ENGINE LH2 INLET PRESSURE AND TEMPERATURE

INCLUDES THE FOLLOWING INSTRUMENTATION:

V41P1100 } ENG. NO. 1
V41T1101 }
V41P1200 } ENG. NO. 2
V41T1201 }
V41P1300 } ENG. NO. 3
V41T1301 }

MPT-SF2-001 TEST DATA

NOTE:
ASSUMES ENGINE HEAT
LOAD = 5 BTU/SEC/ENG
400 Hz PUMP POWER

SATURATION CURVE

PRESSURIZED ET
(41 TO 44 PSIA ULLAGE)

RECIRC PUMPS OFF
(PRESTART COND)

RECIRC PUMPS ON
(400 Hz)

TOPPING & REPLEN
(15 TO 16 PSIA ULLAGE)
400 Hz

ENGINE PRESTART
BOX (CD13M5000)

PREDICTION WITH
43 TO 46 PSIA ULLAGE

PRESSURE PSIA

TEMPERATURE OF
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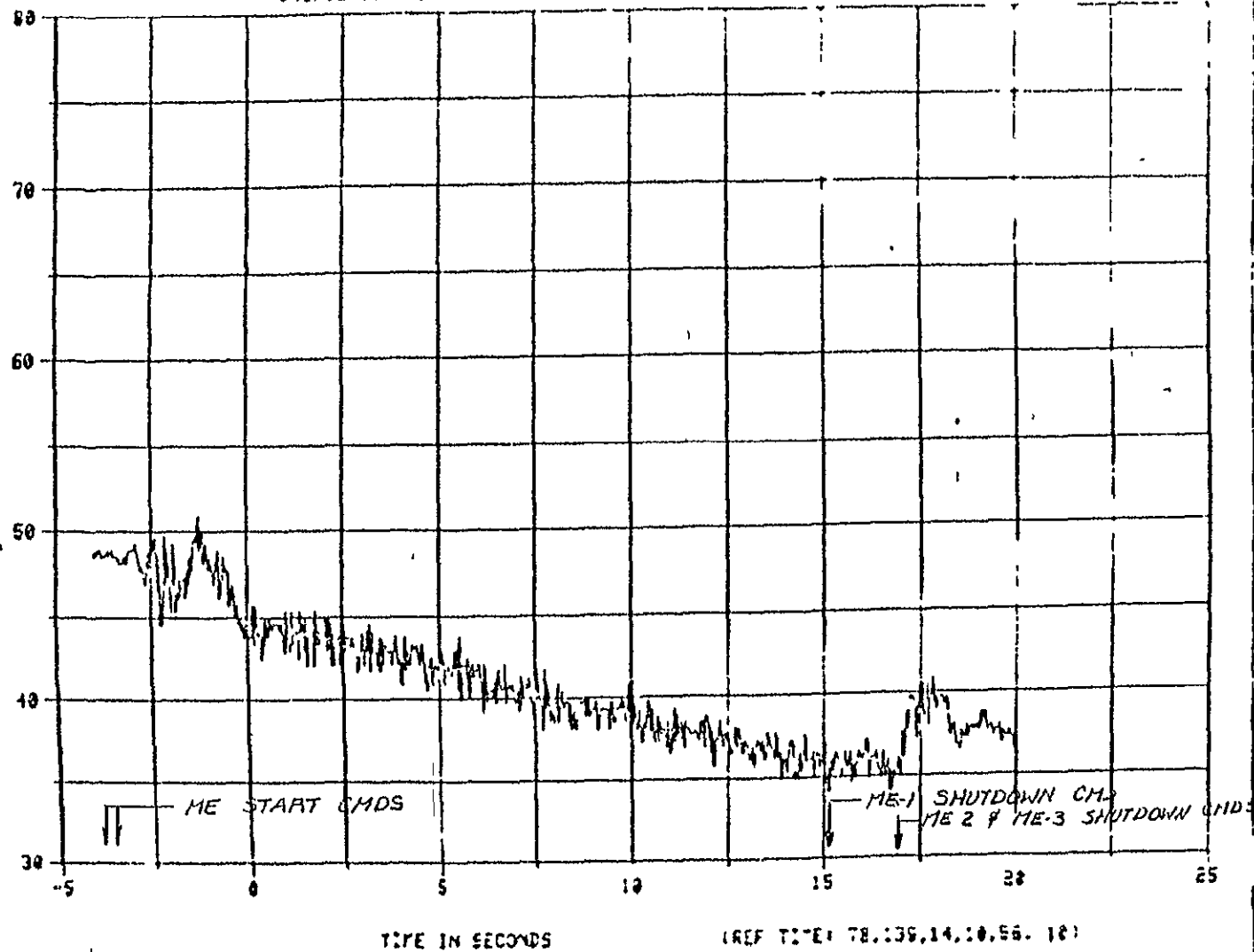
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4.1.1.4 Propellant Feed System. Propellant feed system performance is presented in Figures 4.1.1.4-1 through -10. Overall engine inlet conditions, pressure, temperature, and NPSP, expanded plots for IH_2 pressure transients and IO_2 start pressure transient are provided for Engine No. 2 which was selected as typical. IO_2 surge pressures during shutdown are provided for Engine No. 1 and Engine No. 2 inlets. The propellant feed system performed as expected for MPT-SF2 except that during engine shutdown, peak IO_2 engine inlet pressures differed more than expected for the three engines with Eng. No. 1 inlet pressure being higher than predicted. Feedline pressures for steady state flow were within predicted limits and NPSP requirements were met. For MPT-SF2, both the engine start and shutdown commands were staggered. The engines were started at .120 second intervals. Engine shutdown was initiated by Engine No. 1 which was followed after 1.8 seconds by both Engine No. 2 and Engine No. 3. For engine shutdown, IO_2 surge pressures were approximately 62 psi at the Orb/SSME interface, and peak inlet pressure for Engine No. 1 was 175 psia. Maximum design operating pressure is 199 psia for the 12-inch feedlines. An increase in the IO_2 Inlet Pressure for Engine No. 1 was noted after cutoff. This increase is greater than predicted and is being investigated. Minimum Orb/SSME IO_2 inlet pressure was 68 psia during engine start. IH_2 start slump was negligible and the shutdown surge pressure was about 2.5 psi.

FIGURE 4.1.1.4-1

U41P12J0C MPS-ENG NO 2 LHM INLET PRESS

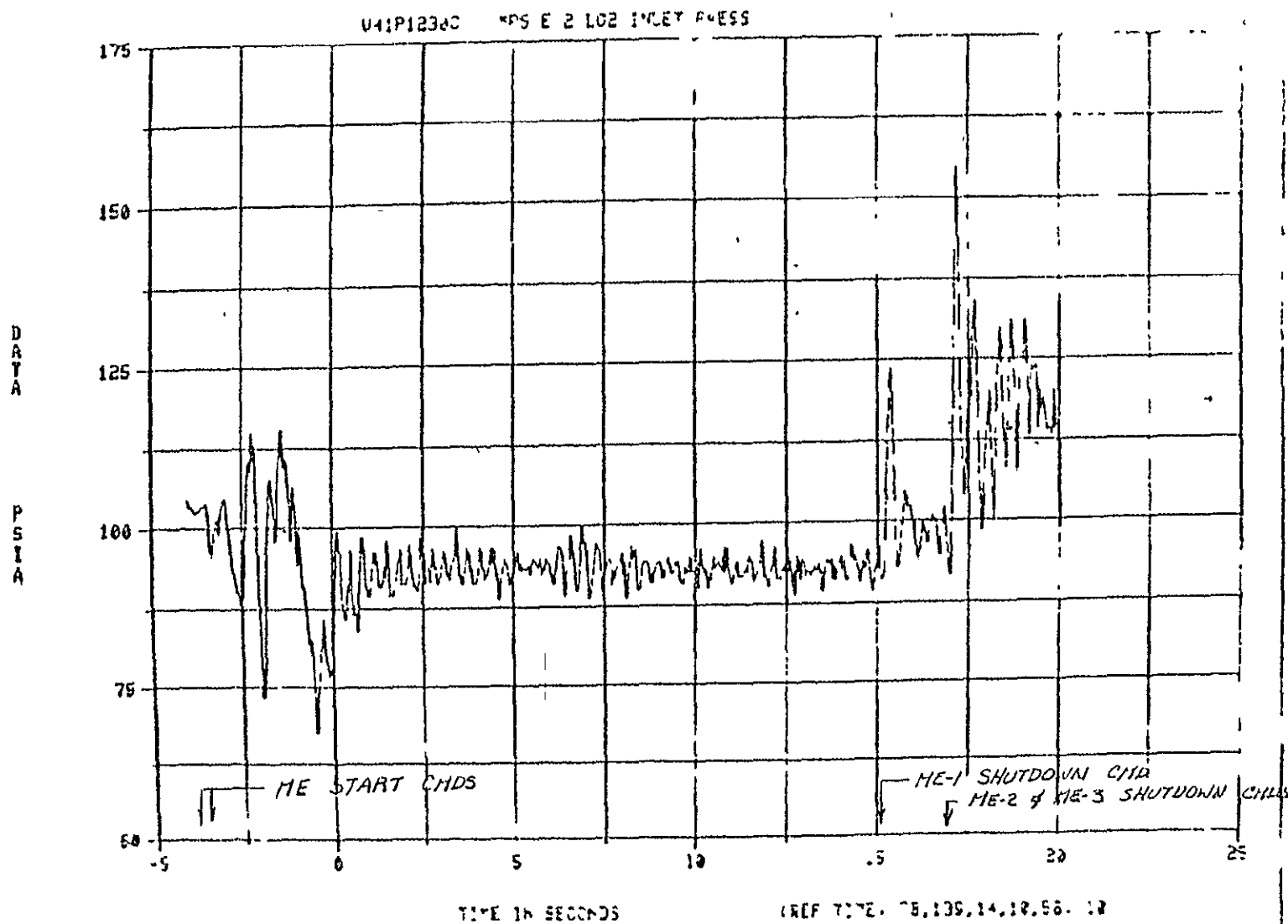


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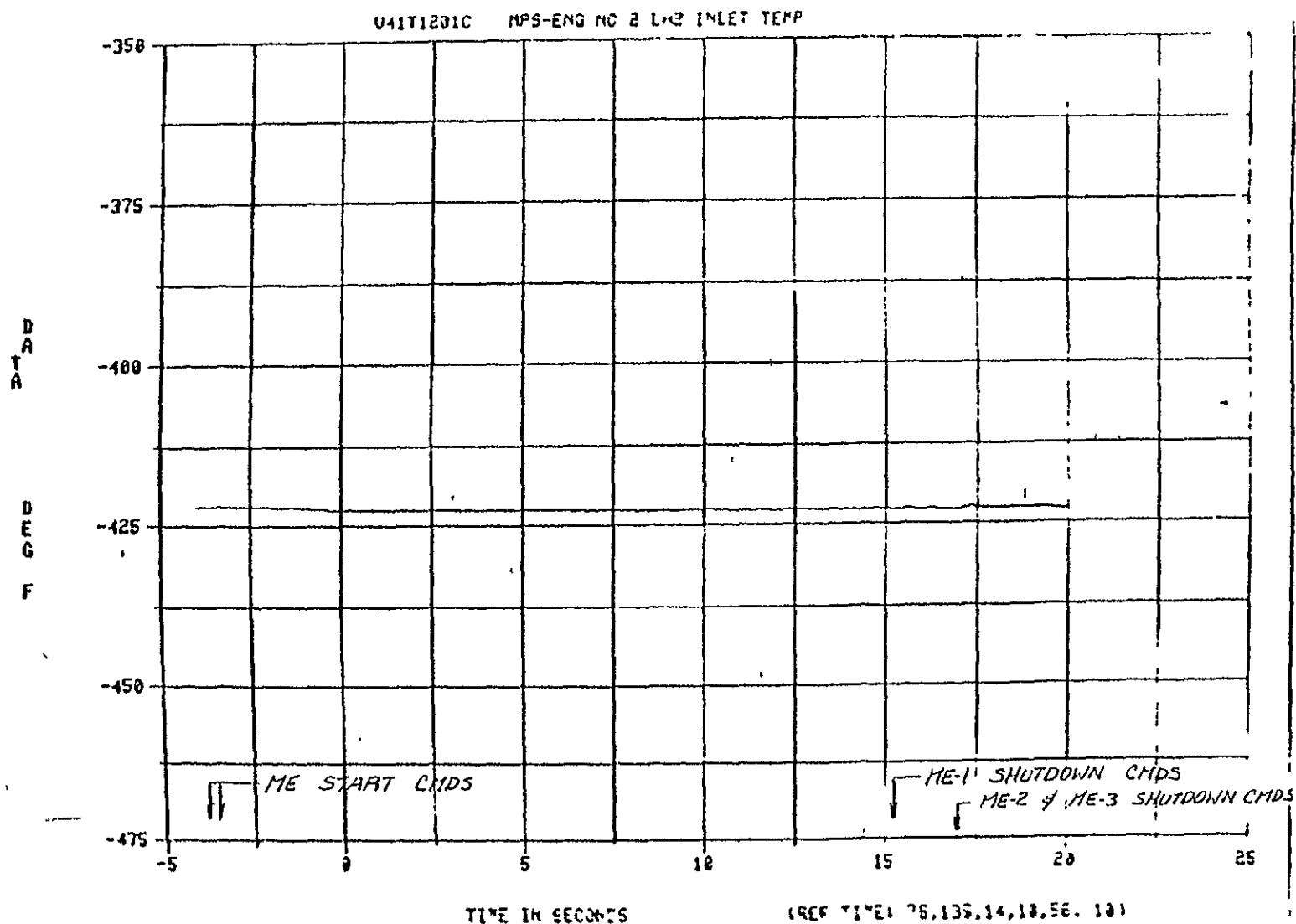
FIGURE 4.1.1.4-2



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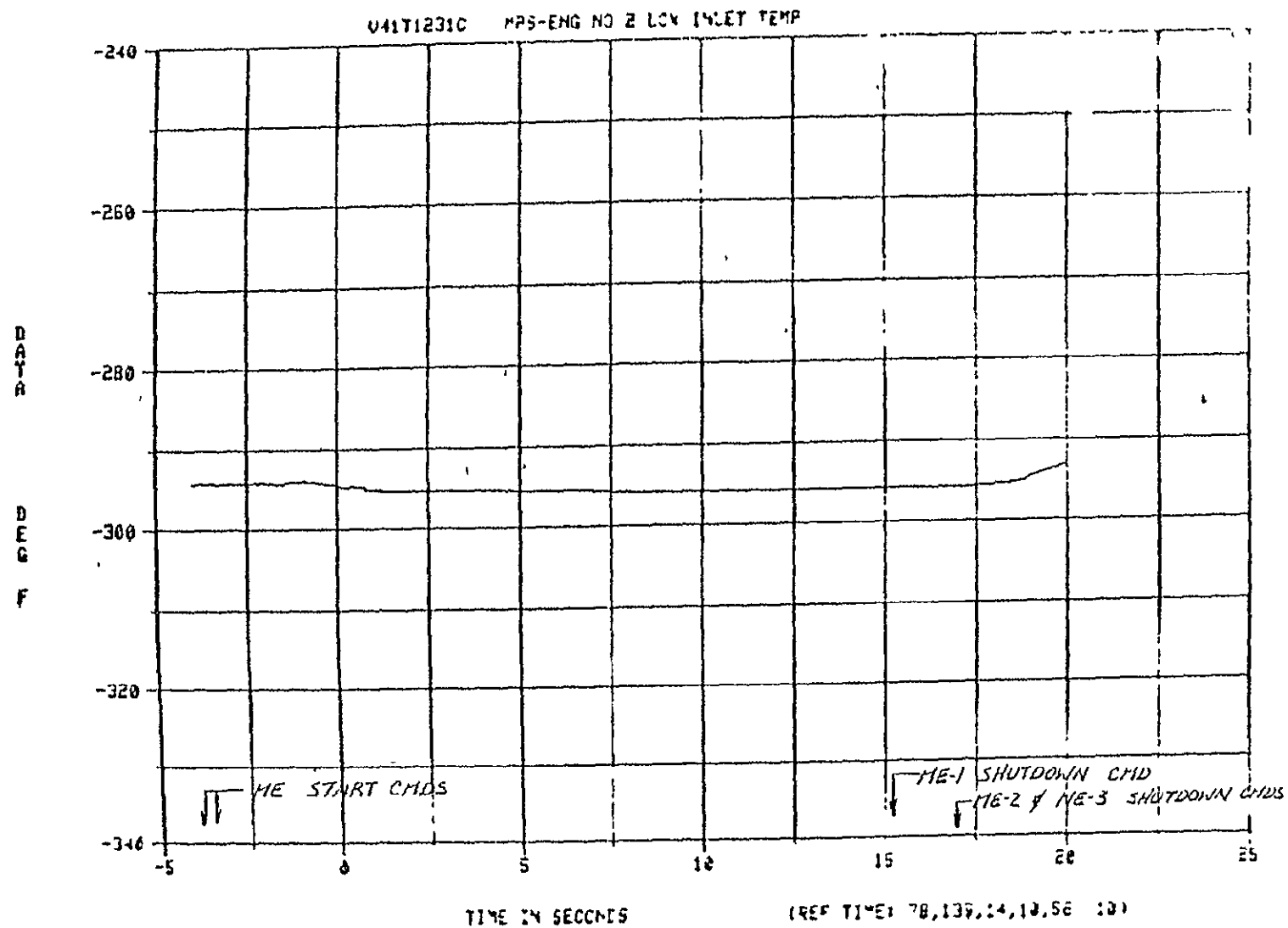
FIGURE 4.1.1.4-3



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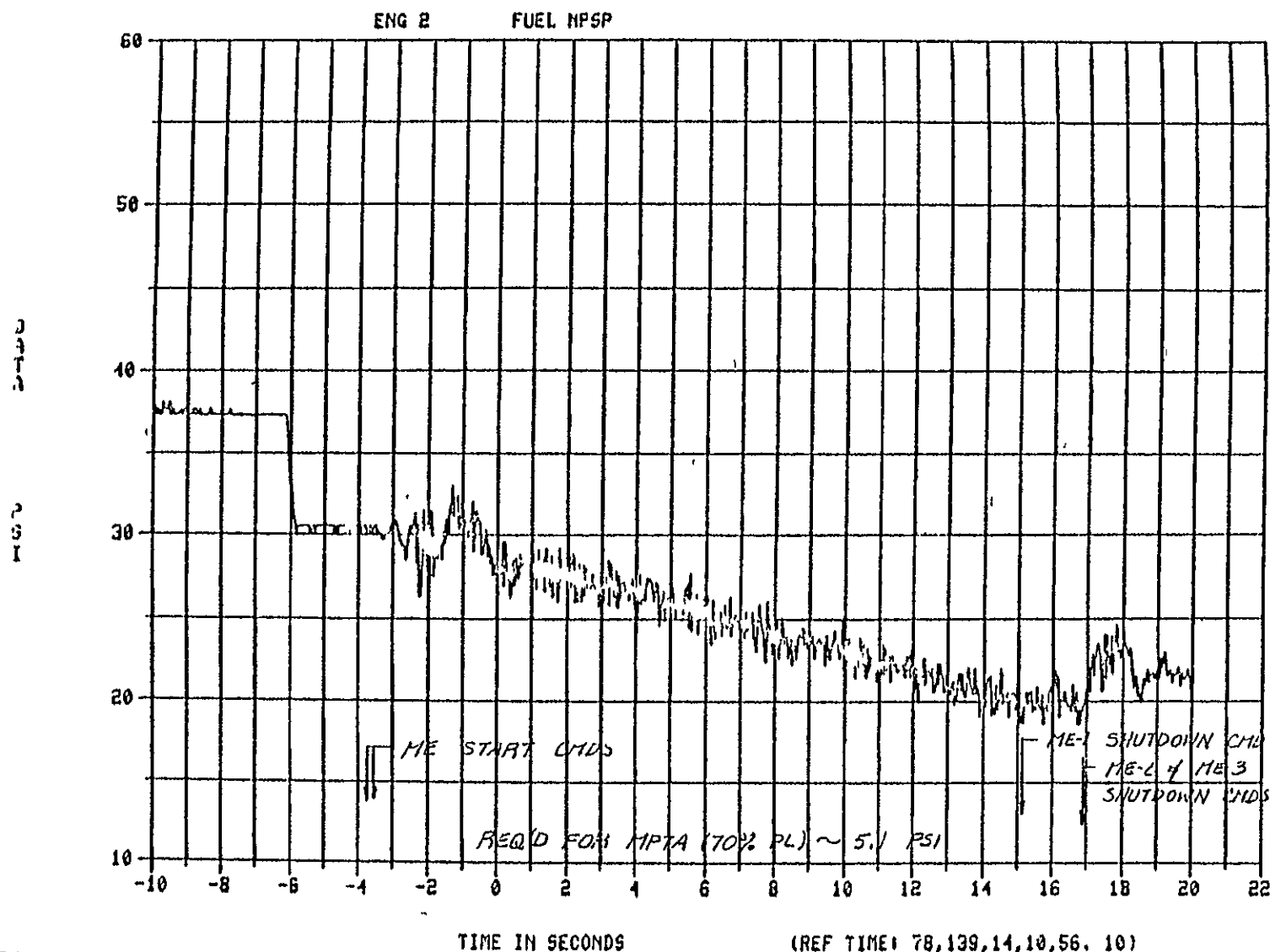
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FIGURE 4.1.1.4-4



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FIGURE 4.1.1.4-5



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FIGURE 4.1.4-6

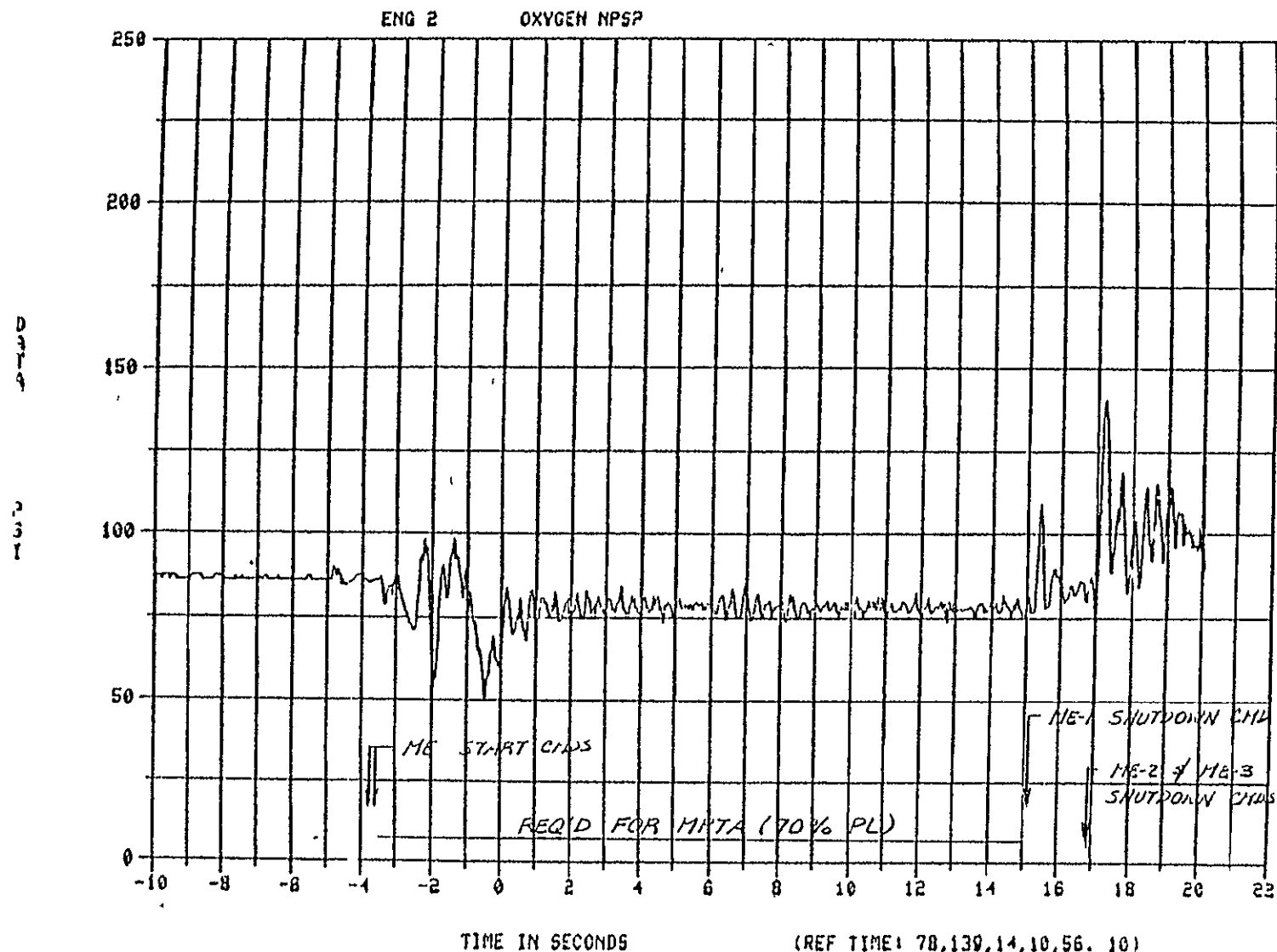
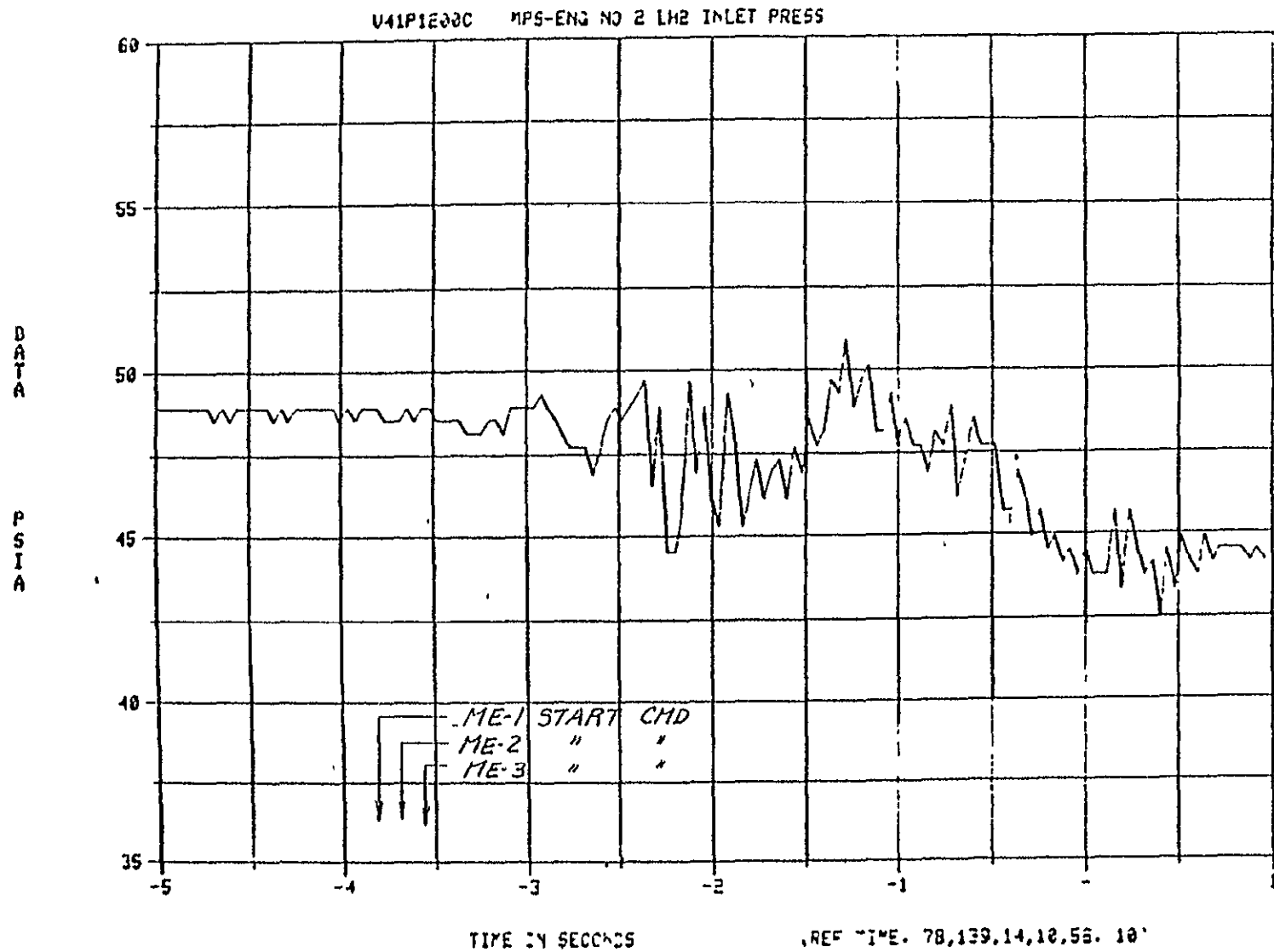


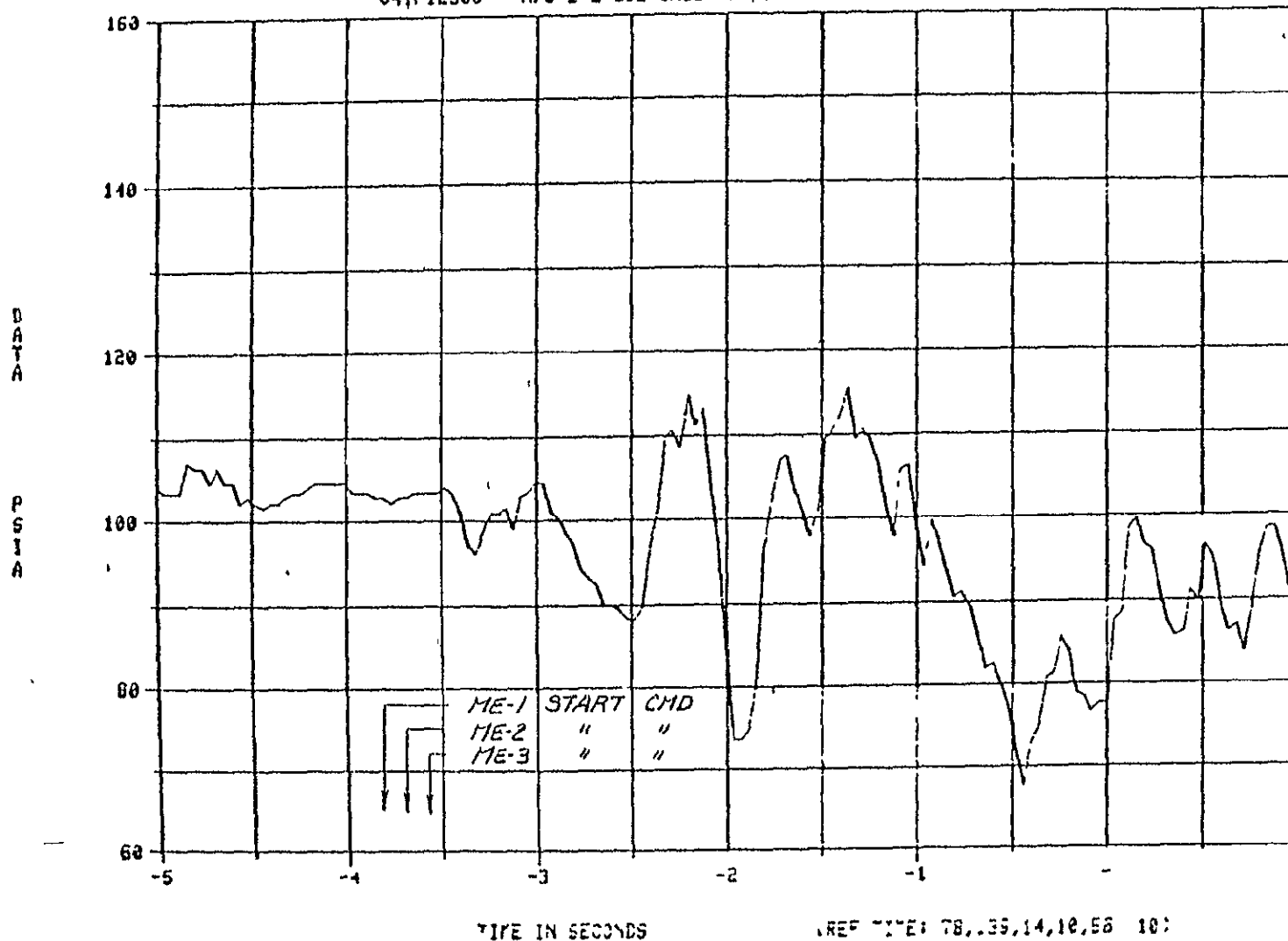
FIGURE 4.1.1.4-7



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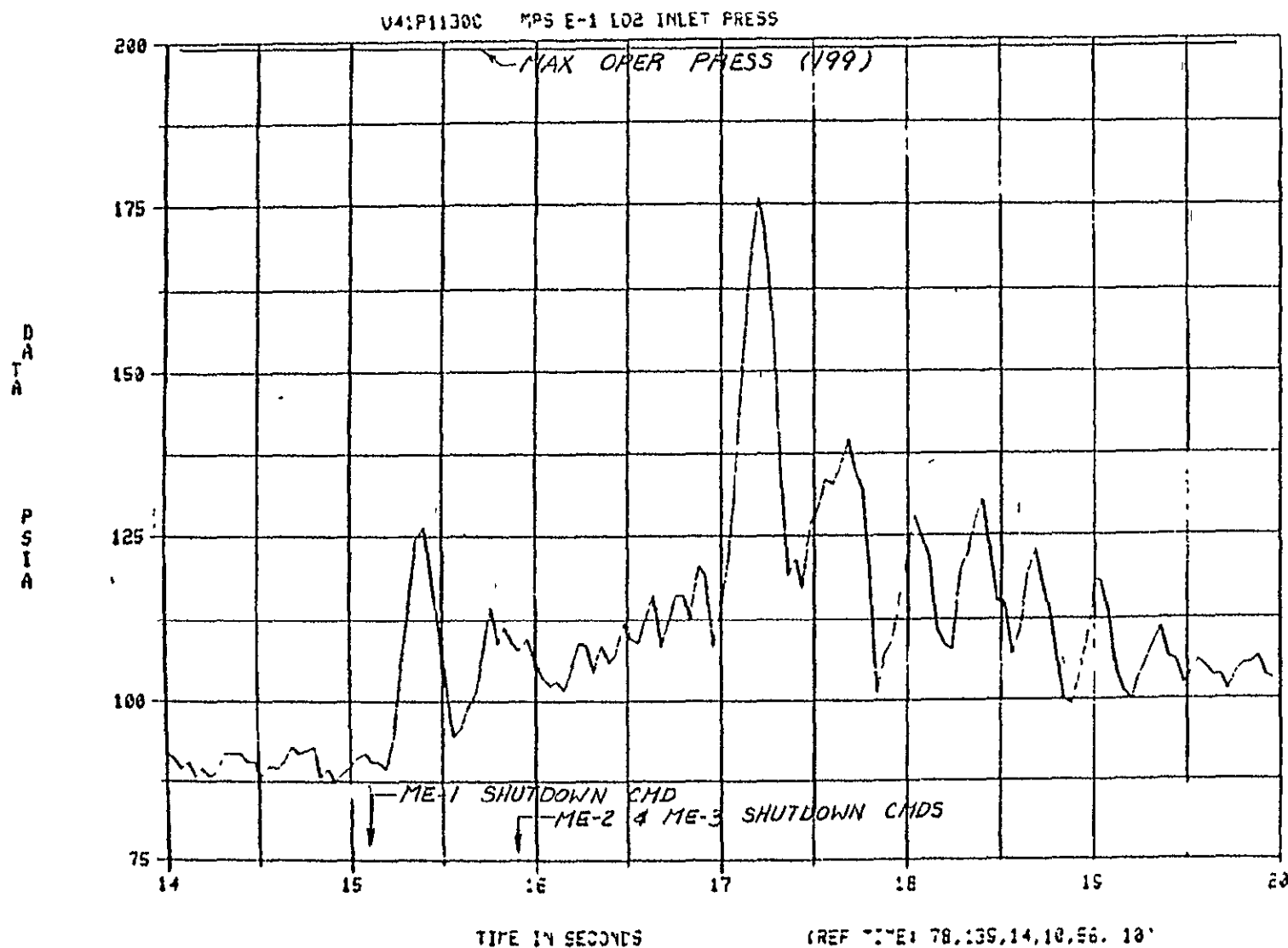
FIGURE 4.1.1.4-8

V41P1230C MPS E-2 L02 INLET PRESS



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FIGURE 4.1.1.4-9

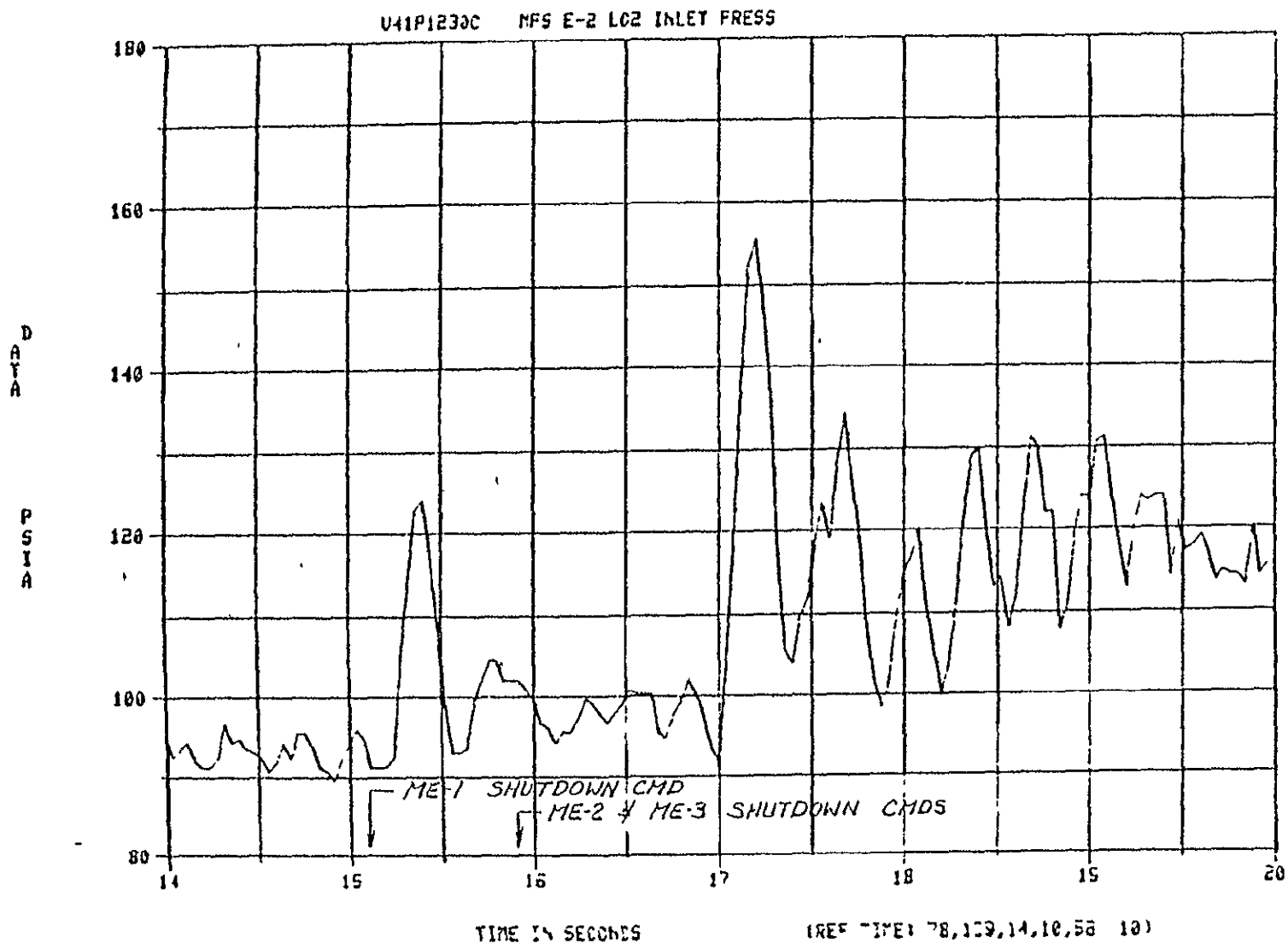


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TEST DATE MAY 19, 1978

FIGURE 4.1.1.4-10



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4.1.1.5 Pneumatic Systems

4.1.1.5.1 Helium System. The performance of the Helium System was different than the required baseline because of an operational change made necessary to avoid an engine shutdown in the event of a possible 750 psig regulator failure. The operational change performed was to open the crossover solenoid valves prior to start of Auto Sequence. However, because of this change and the fact that the regulator for Engine No. 1 was operating out-of-spec high, vehicle supplied helium for all three engines was supplied from the Engine No. 1 Storage Bottle. This supply situation existed from start of Auto Sequence through post-firing surges except for the subburner purge time period. System friction pressure losses were high enough with the flowrate requirements for this purge to bring the individual engine regulators on-line.

The Storage Bottle pressures and temperatures for Auto Sequence and Firing are shown on Figures 4.1.1.5.1-1 through -8. The usage from Engine No. 1 Bottle versus 2 or 3 can be easily seen on these figures.

The Orb/SSME interface pressures and temperatures during Auto Sequence and Firing are presented on Figures 4.1.1.5.1-9 through -14. These figures confirm the high regulator pressure for Engine No. 1. They also show that the Orb/SSME interface pressure requirements of 700-800 psia were violated for Engine No. 1. All interface temperatures were within the requirements except for Purge Sequence 3 when the temperature dropped below the band because of the low purge rates. This performance was not expected. For the next firing test, it is recommended that the regulator component problems be fixed so that crossover valve operation can be returned to normal. Also, the problem with the regulator that supplies Engine No. 1 should be corrected.

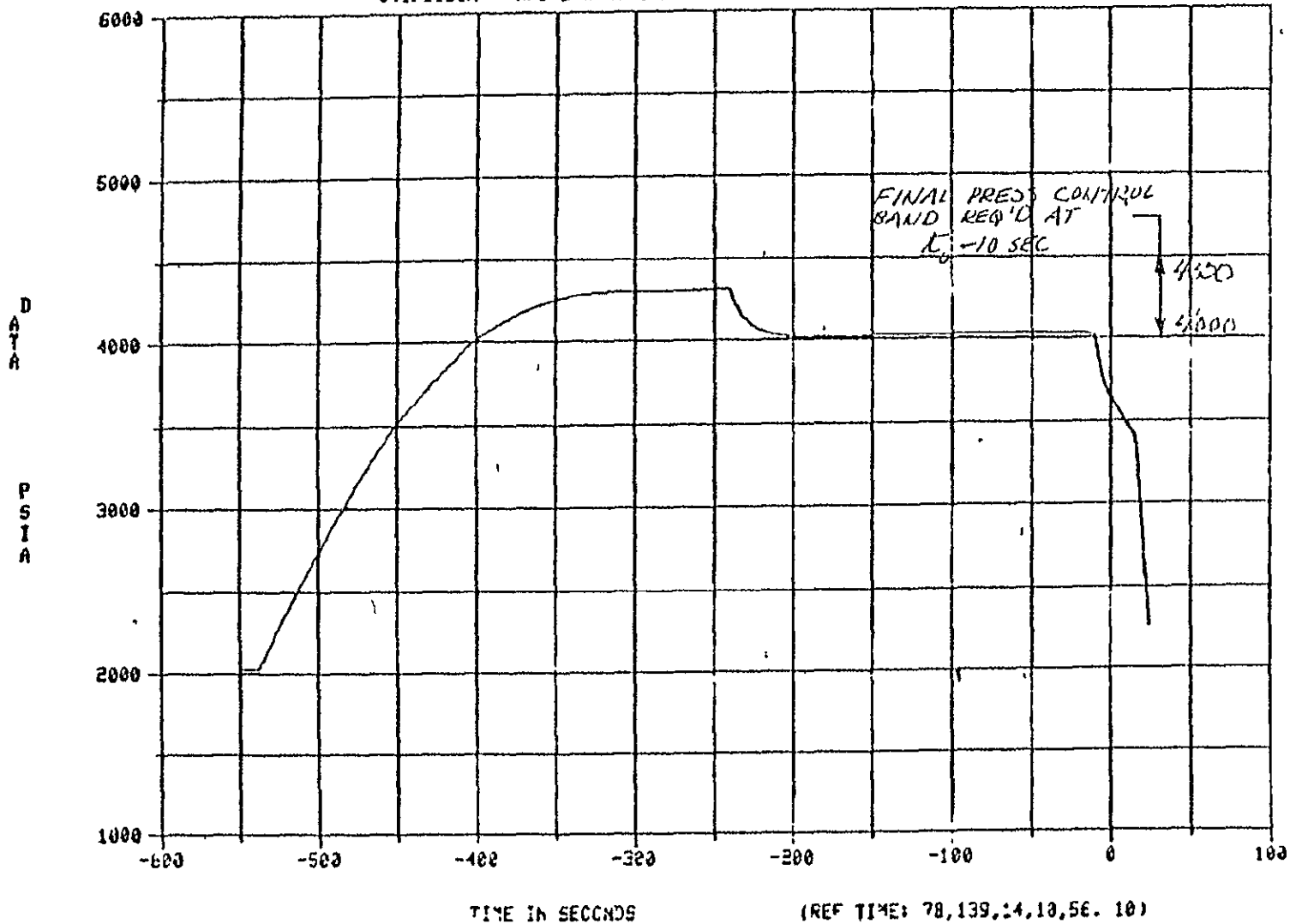
The Pneumatic Actuation System performed as required for this test. Figure 4.1.1.5.1-15 shows the Surge Chamber pressure. The pressure was above the normal range of 700 -780 psig because of the high regulated pressure and the open crossover valves. However, this pressure level does not create any problems.

4.1.1.5.2 GH₂ Purge System. The GH₂ Purge System satisfied all requirements during this test. The Orb/SSME Interface pressures are shown on Figures 4.1.1.5.2-1 through -3. All three interface pressures were within the required bands of 550-650 psia although Engine 1 was just barely above the minimum requirement. The Orb/SSME interface pressure was a 625 psig which is below the required load of 630-900 psig. This problem will be corrected for the next test by raising the facility GH₂ Purge regulator control band to 720 $\pm$ 50 psig.

The Orb/SSME Interface temperatures were within the required ranges. This data is presented on Figures 4.1.1.5.2-4 through -6.

Figure 4.1.1.5.1-1

U41P1153H MPS-ENG NO 1 HELIUM SUPPLY PRESS

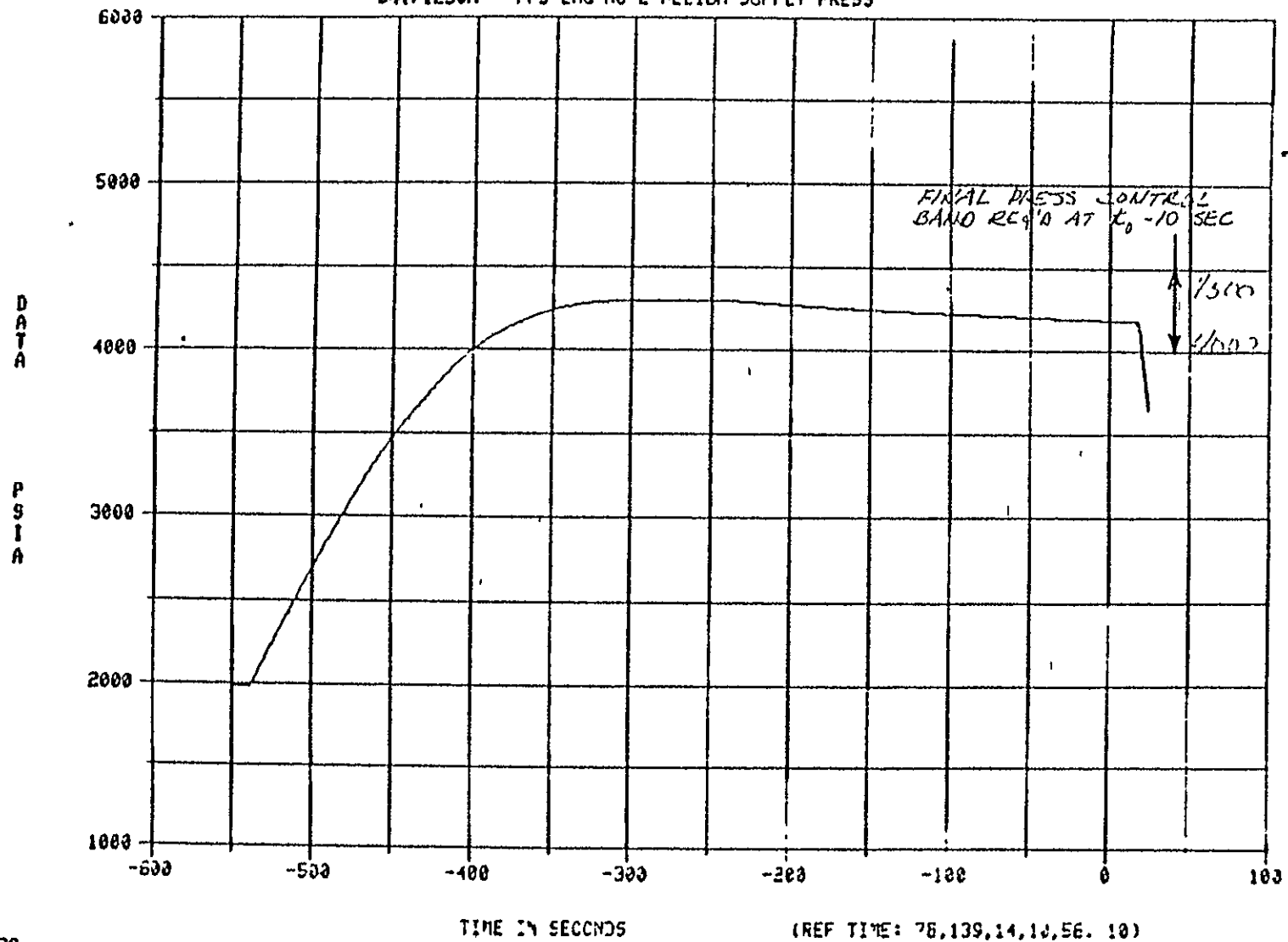


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Figure 4.1.1.5 1-2

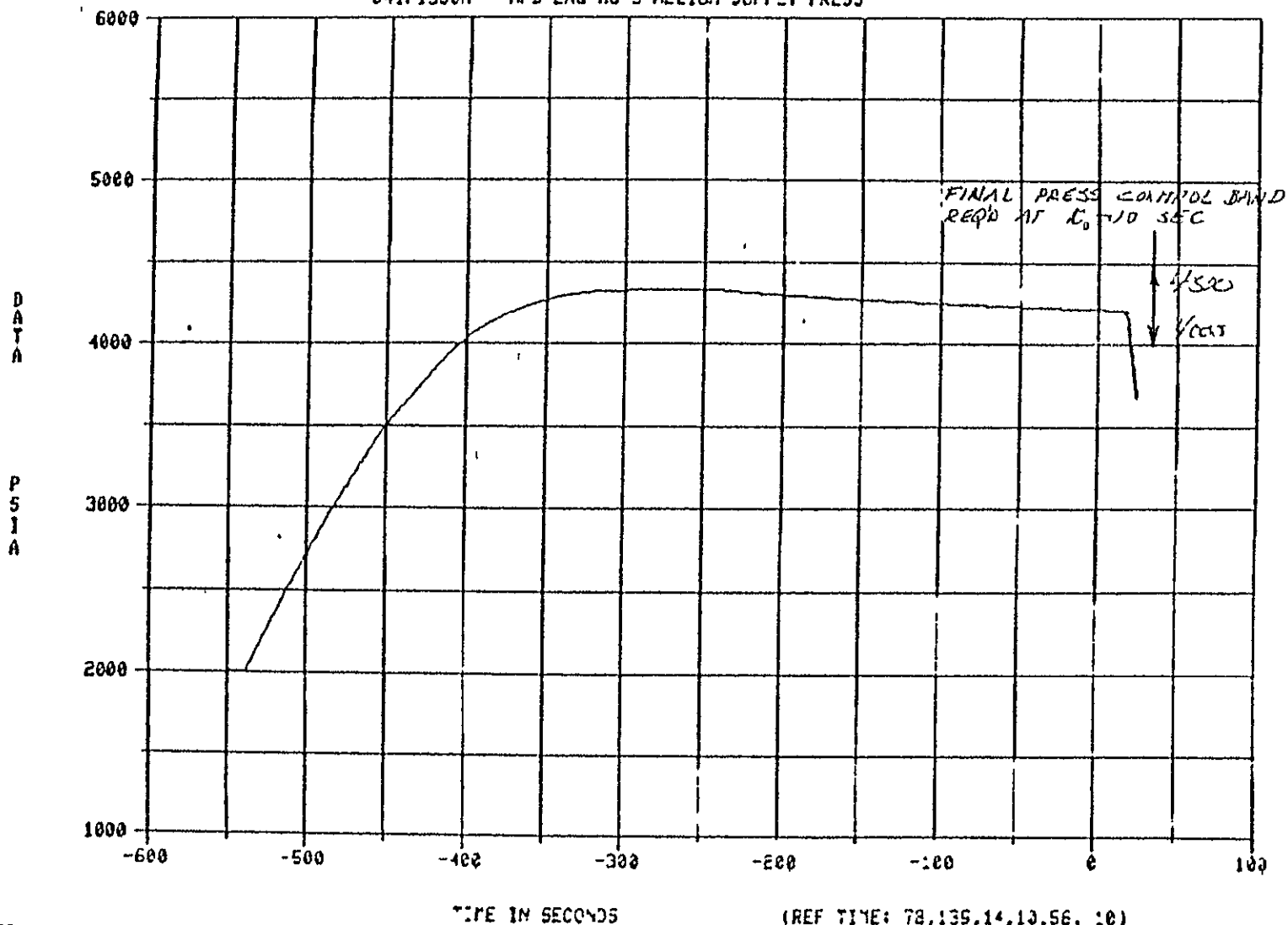
V41P1250H MPS-ENG NO 2 HELIUM SUPPLY PRESS



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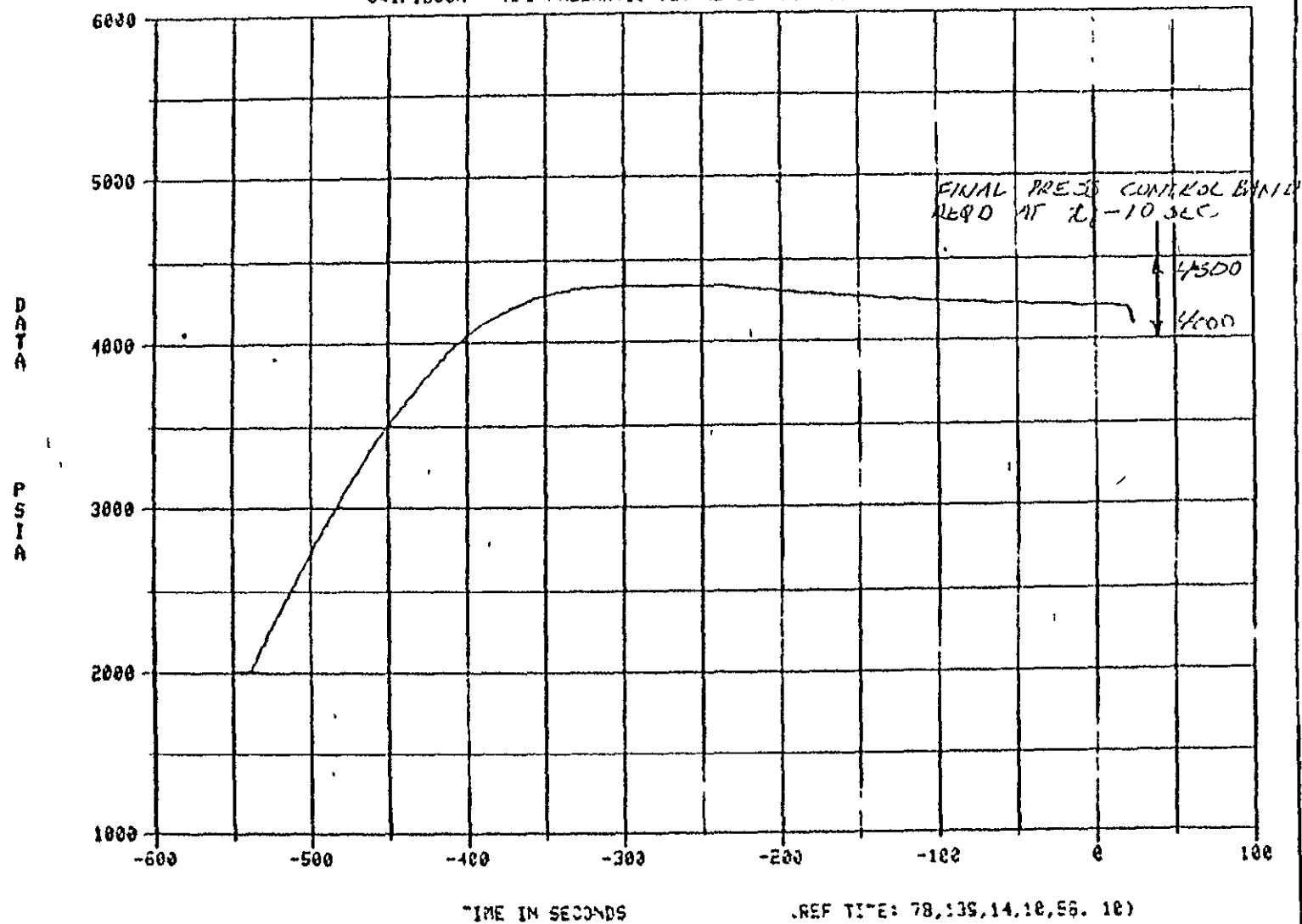
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Figure 4.1.1.5.1-3
U41P1350H MPS-ENG NO 3 HELIUM SUPPLY PRESS



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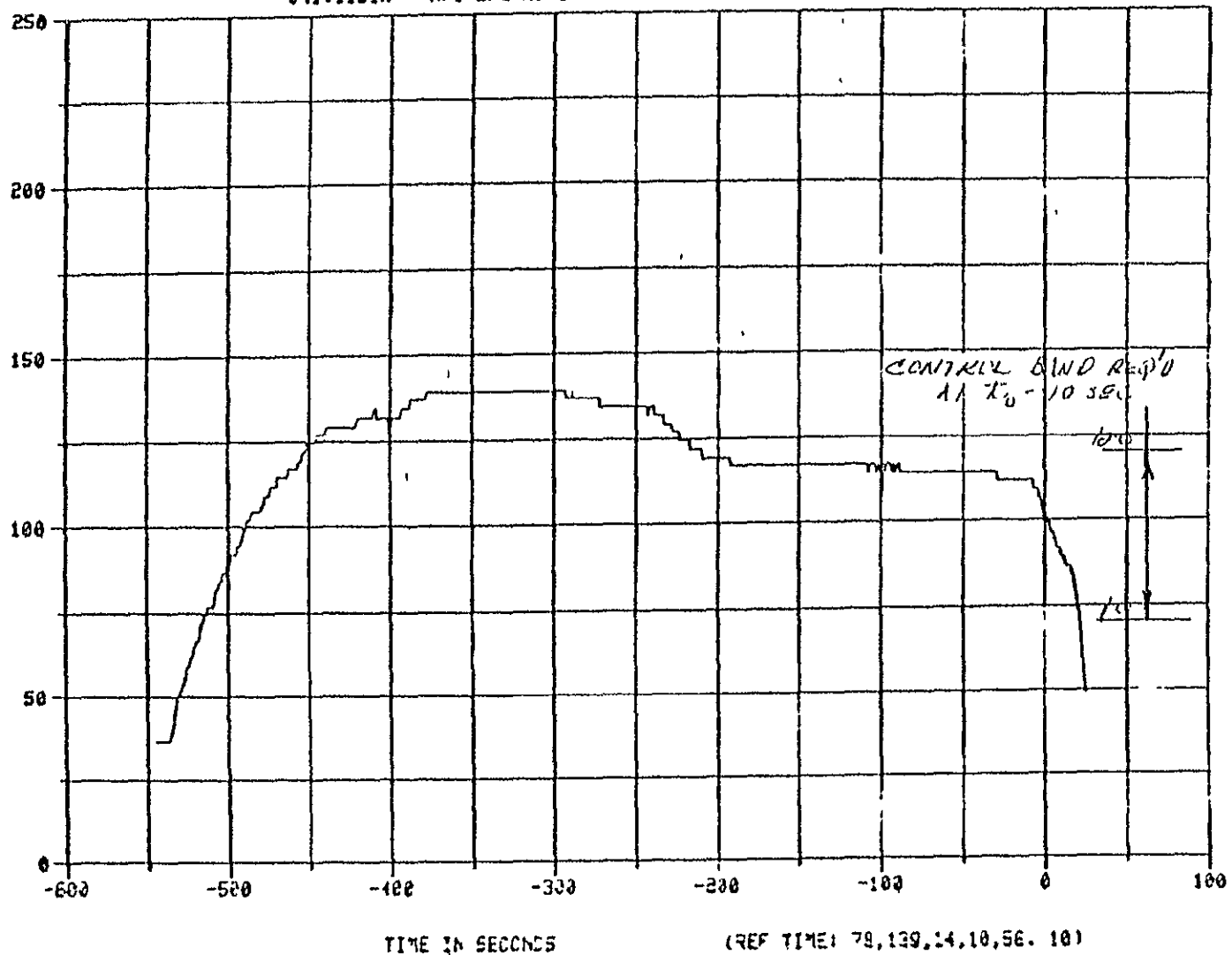
Figure 4.1.1.5.1-4
U41P1623H MPS-PNEUMATIC ULV HE SUPPLY PRESS



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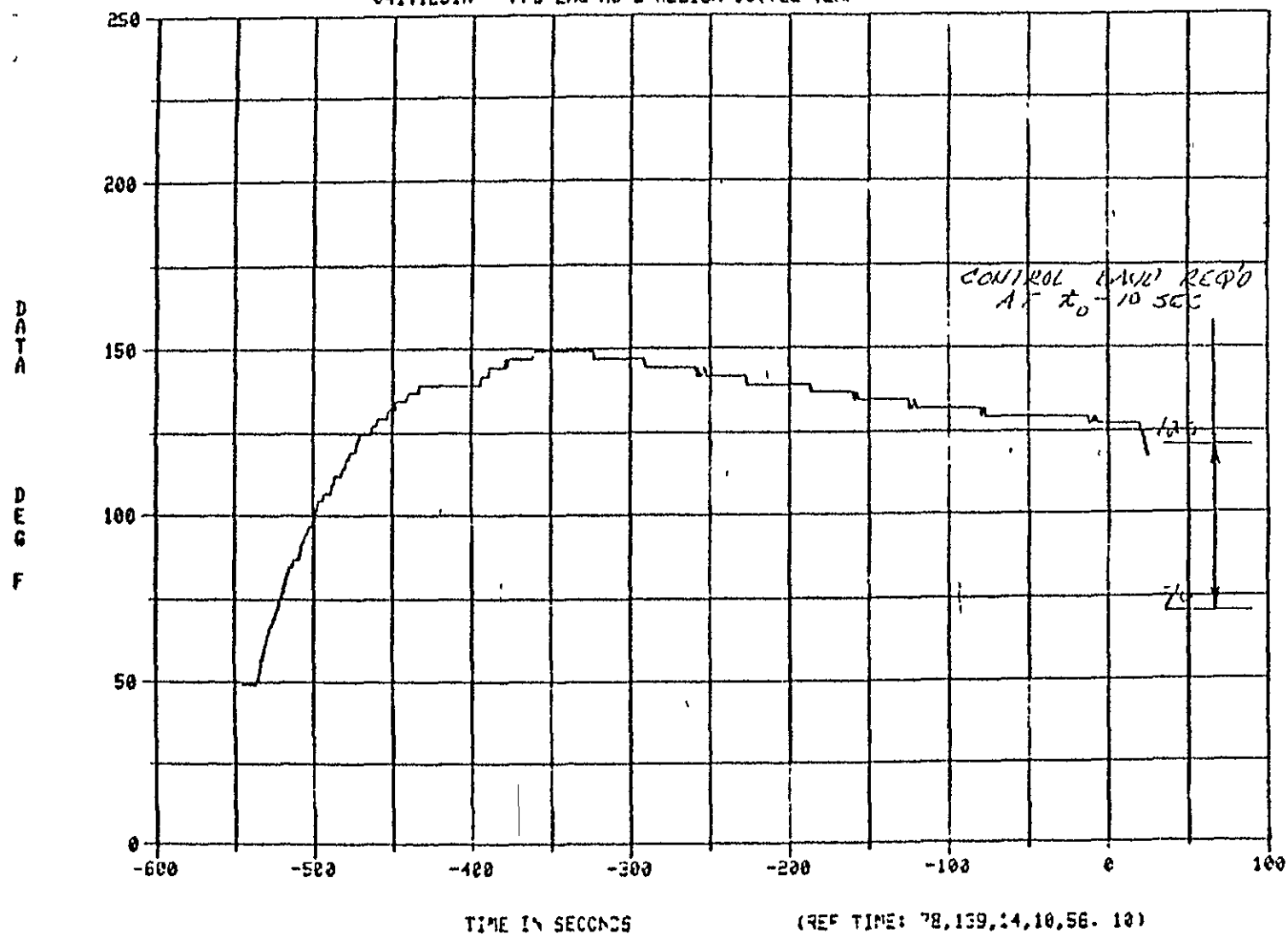
Figure 4.1.1.5.1-5
U41T1151A MPS-ENG NO 1 HELIUM BOTTLE TEMP

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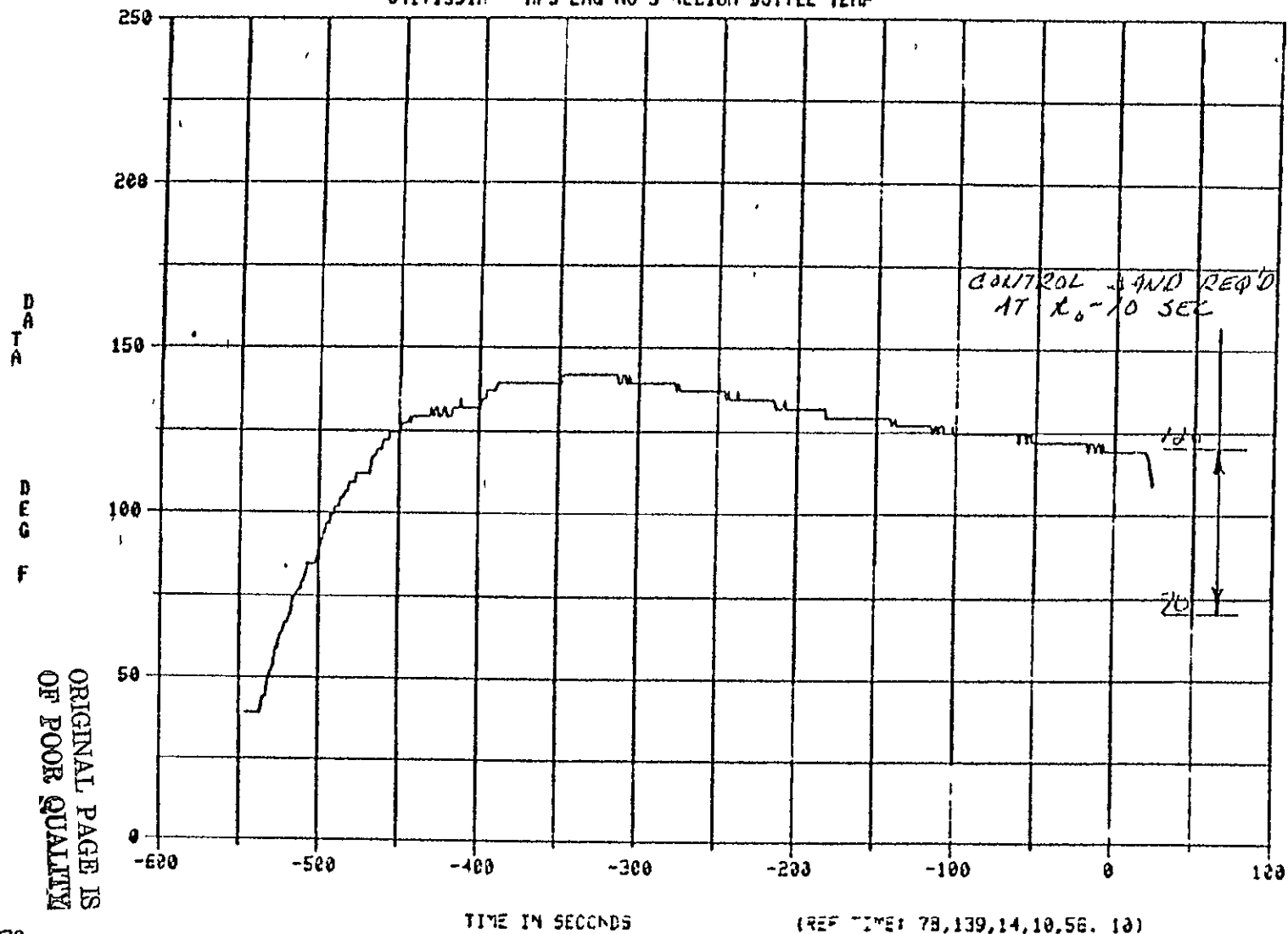
Figure 4.1.1.5.1-6
041T1251A PFS-ENG NO 2 HELIUM BOTTLE TEMP



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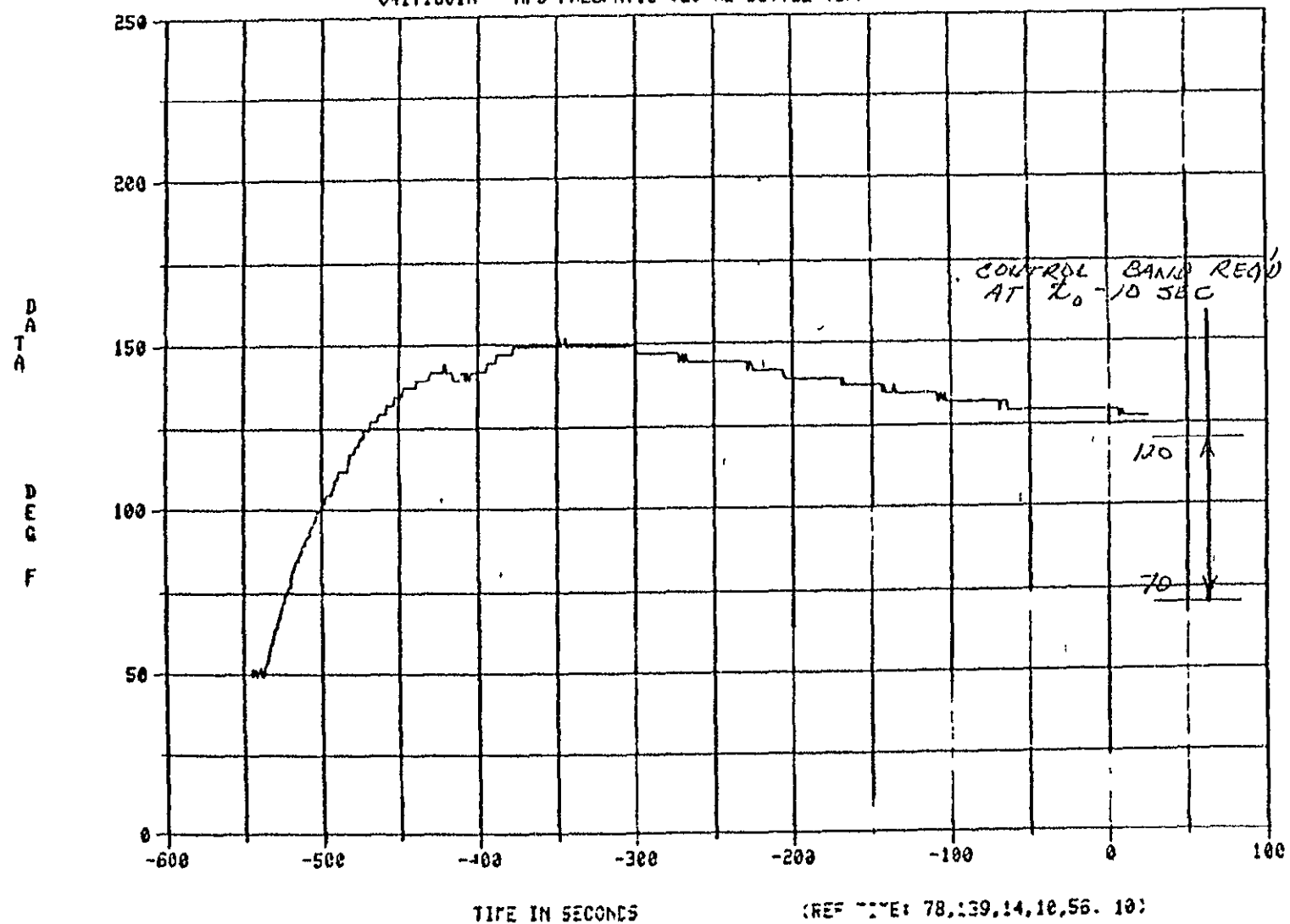
Figure 4.1.1.5.1-7
U41T1351A MPS-ENG NO 3 HELIUM BOTTLE TEMP



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Figure 4.1.1.5.1-8

V41T1601A MPS-PNEUMATIC ULV HE BOTTLE TEMP



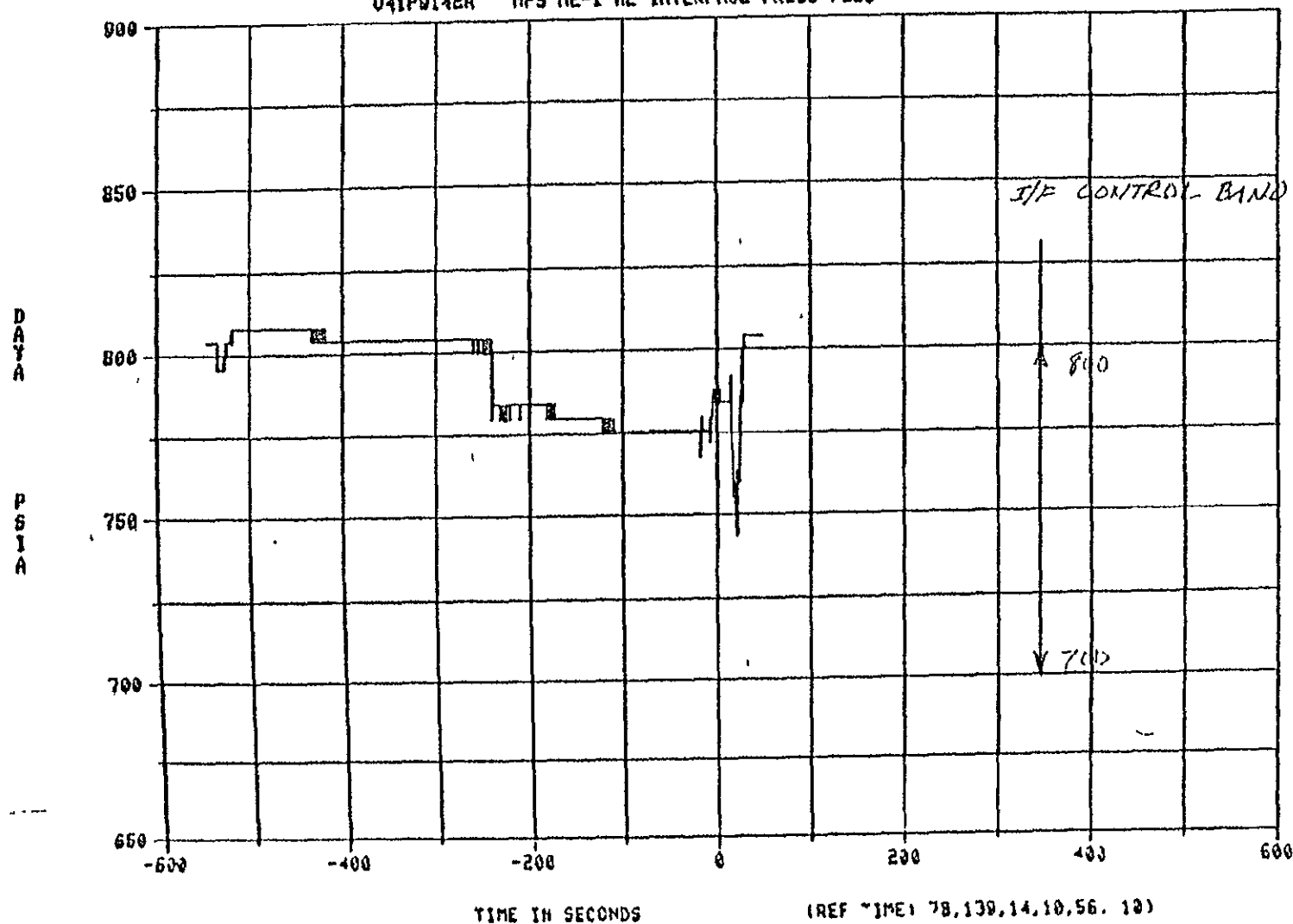
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SD78-SH-0125

SPACE DIVISION (ROCKWELL)
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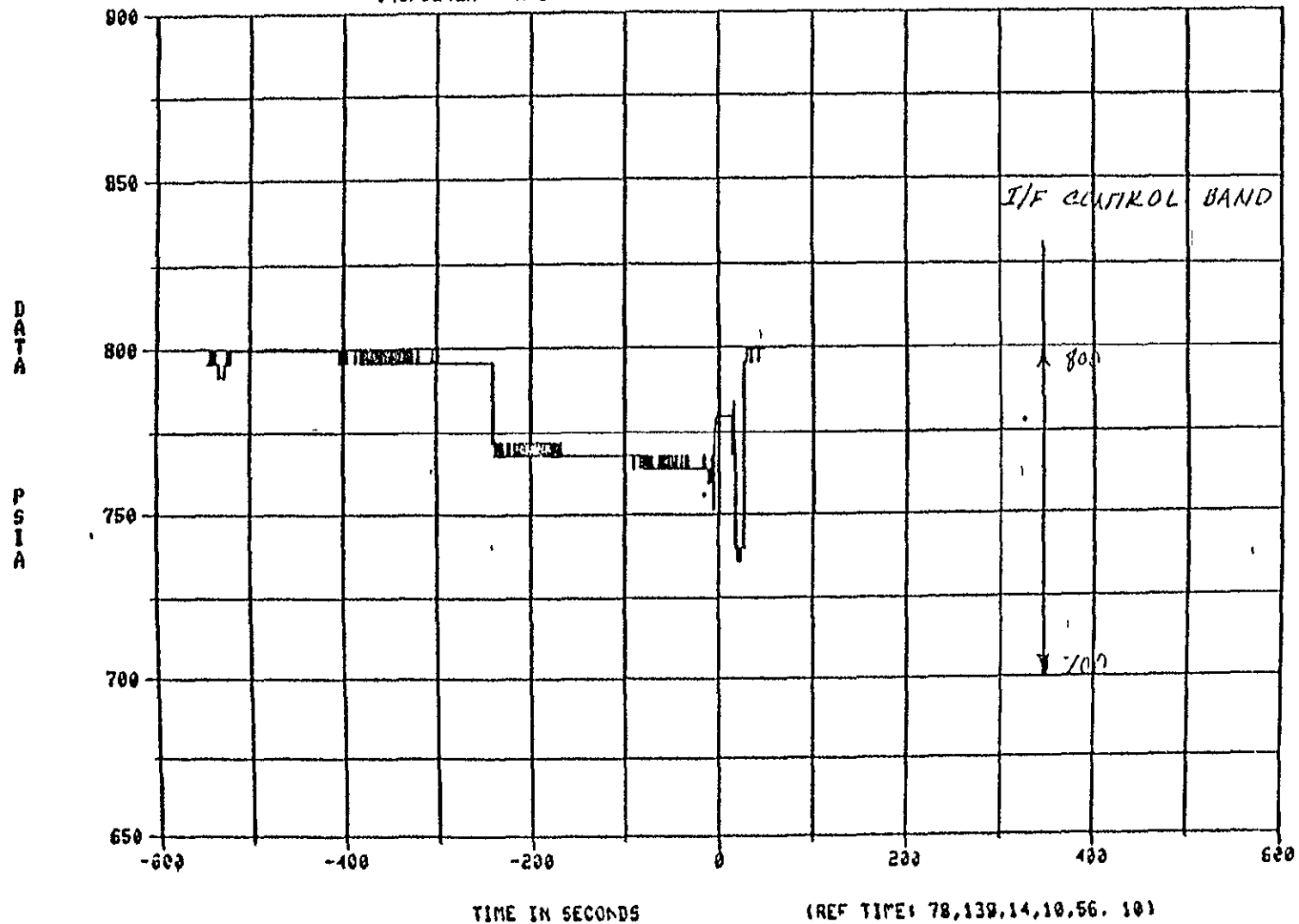
TEST NUMBER MPT9F2
TEST DATE MAY 10, 1978

Figure 4.1.1.5.1-9
V41P9142A MP9 ME-1 HE INTERFACE PRESS P229



14578

Figure 4.1.1 5.1-10
V41P9242A MPS ME-2 HE INTERFACE PRESS P230

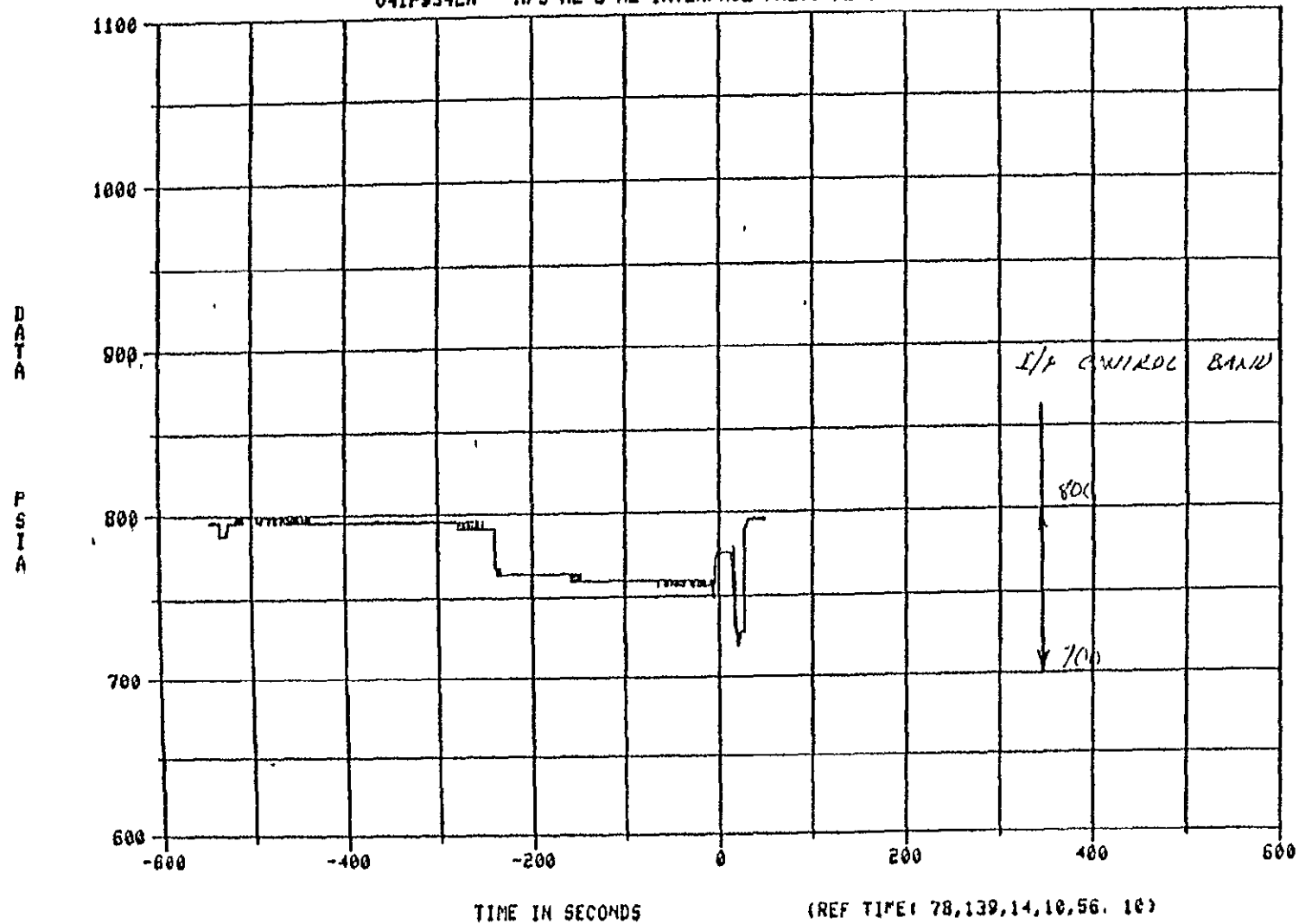


14578

SPACE DIVISION (ROCKWELL)
PROPULSION ANALYSIS GROUP

TEST NUMBER MPTSF2
TEST DATE MAY 10, 1978

Figure 4.1.1.5.1-11
U41P9342A MPS NE-3 HE INTERFACE PRESS P231



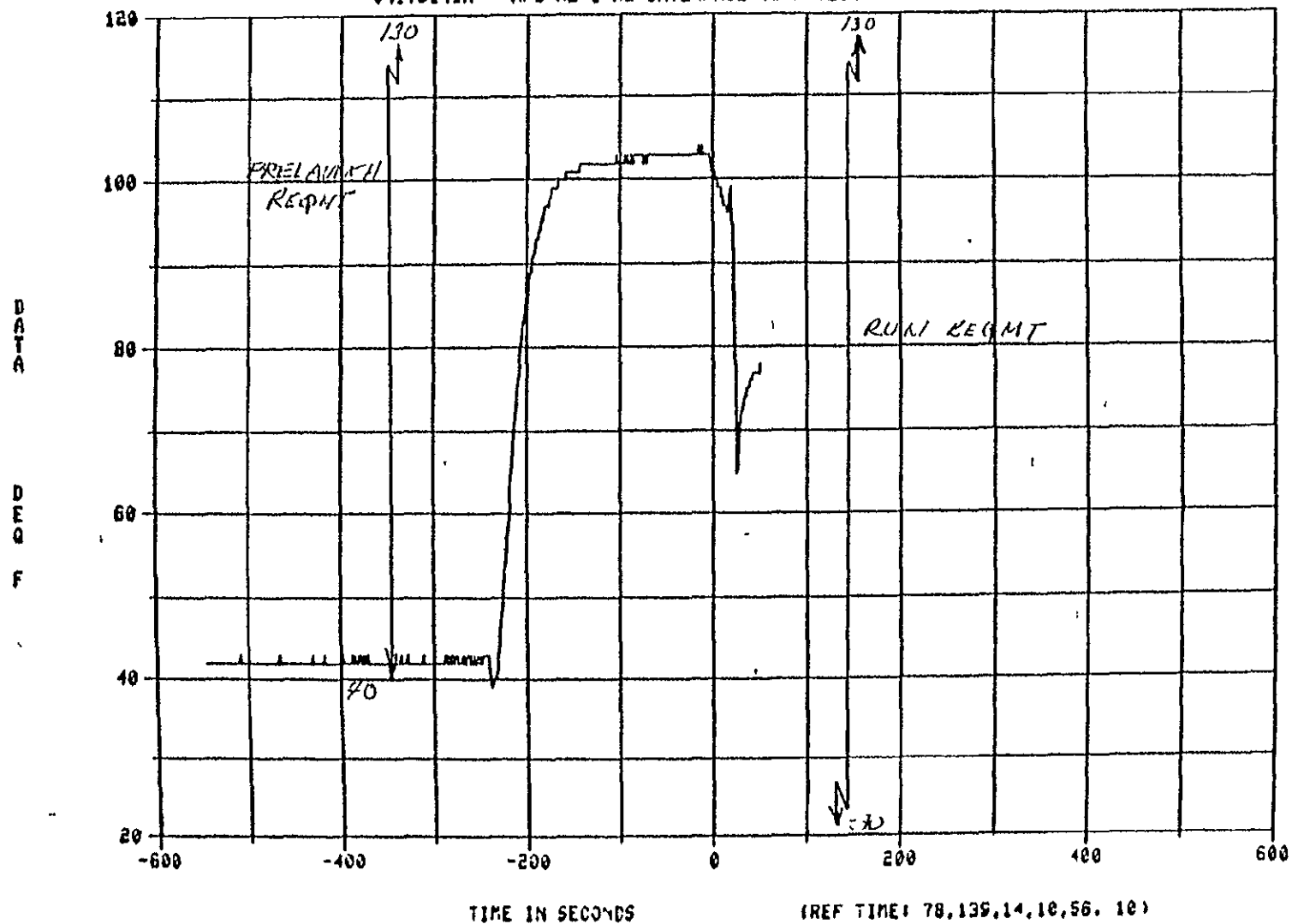
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Figure 4.1.1.5.1-12
U41T9141A MPS ME-1 HE INTERFACE TEMP T204

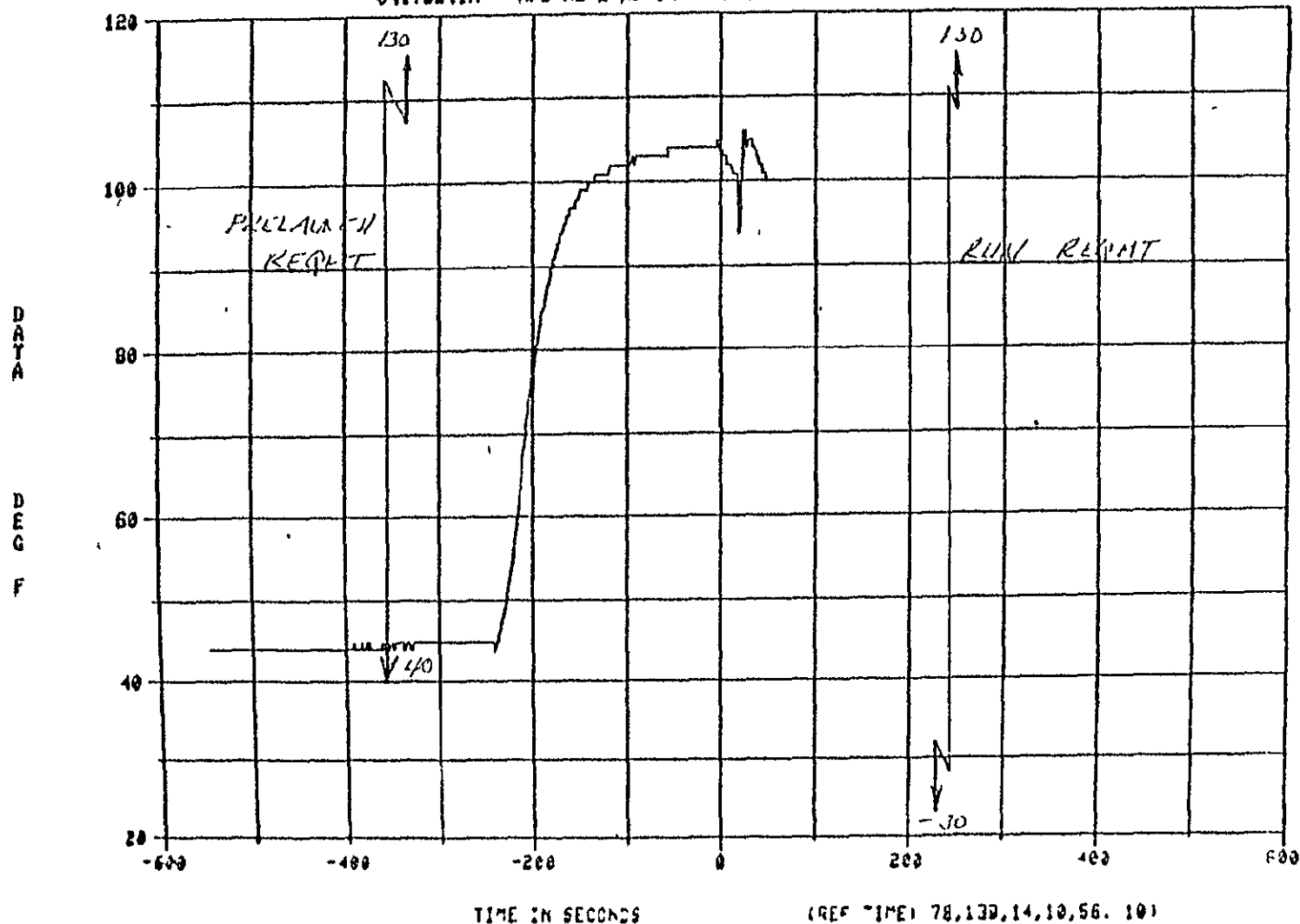


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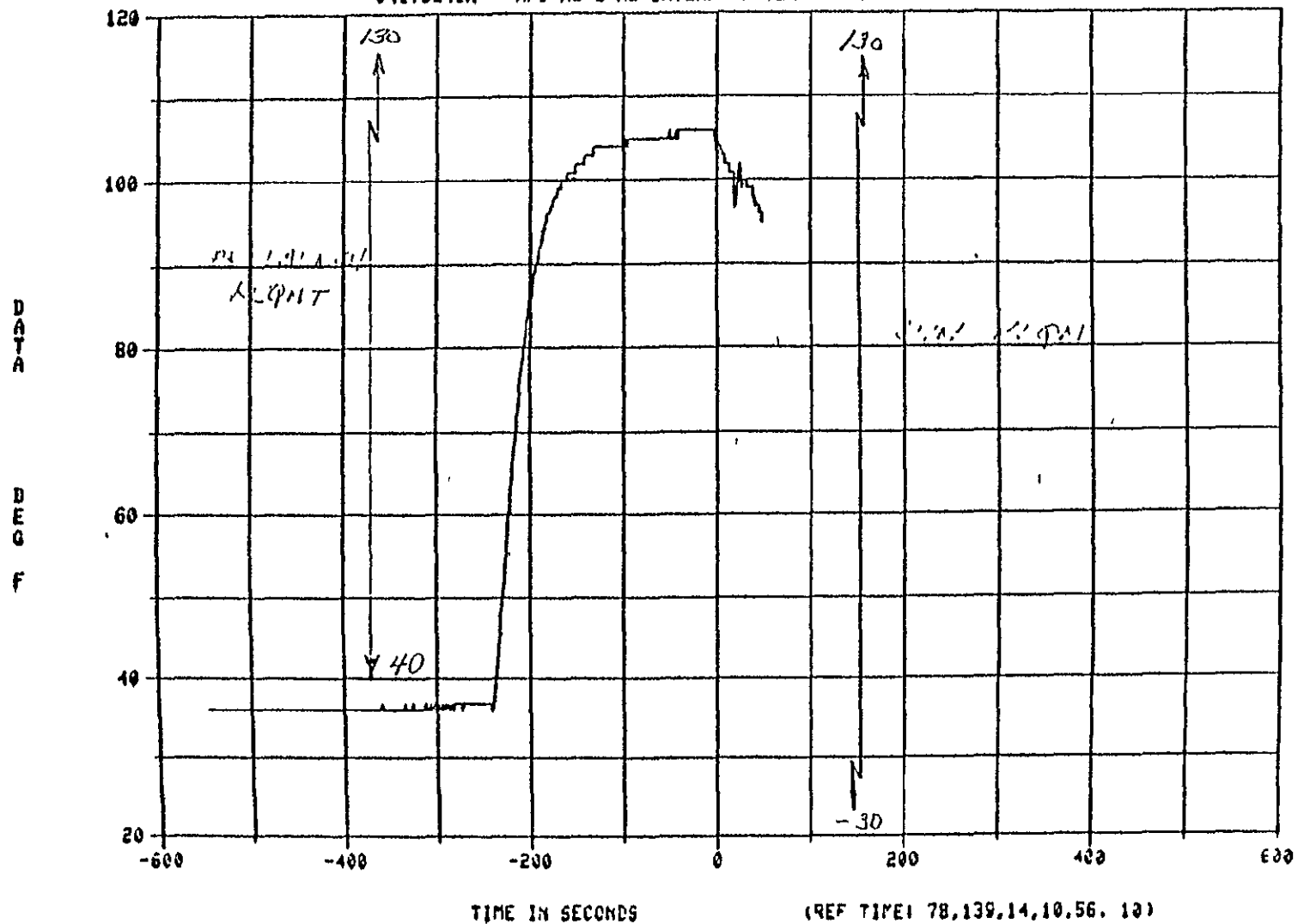
- 90 -

Figure 4.1.1.5.1-13
U41T9241A MPS ME-2 HE INTERFACE TEMP T205



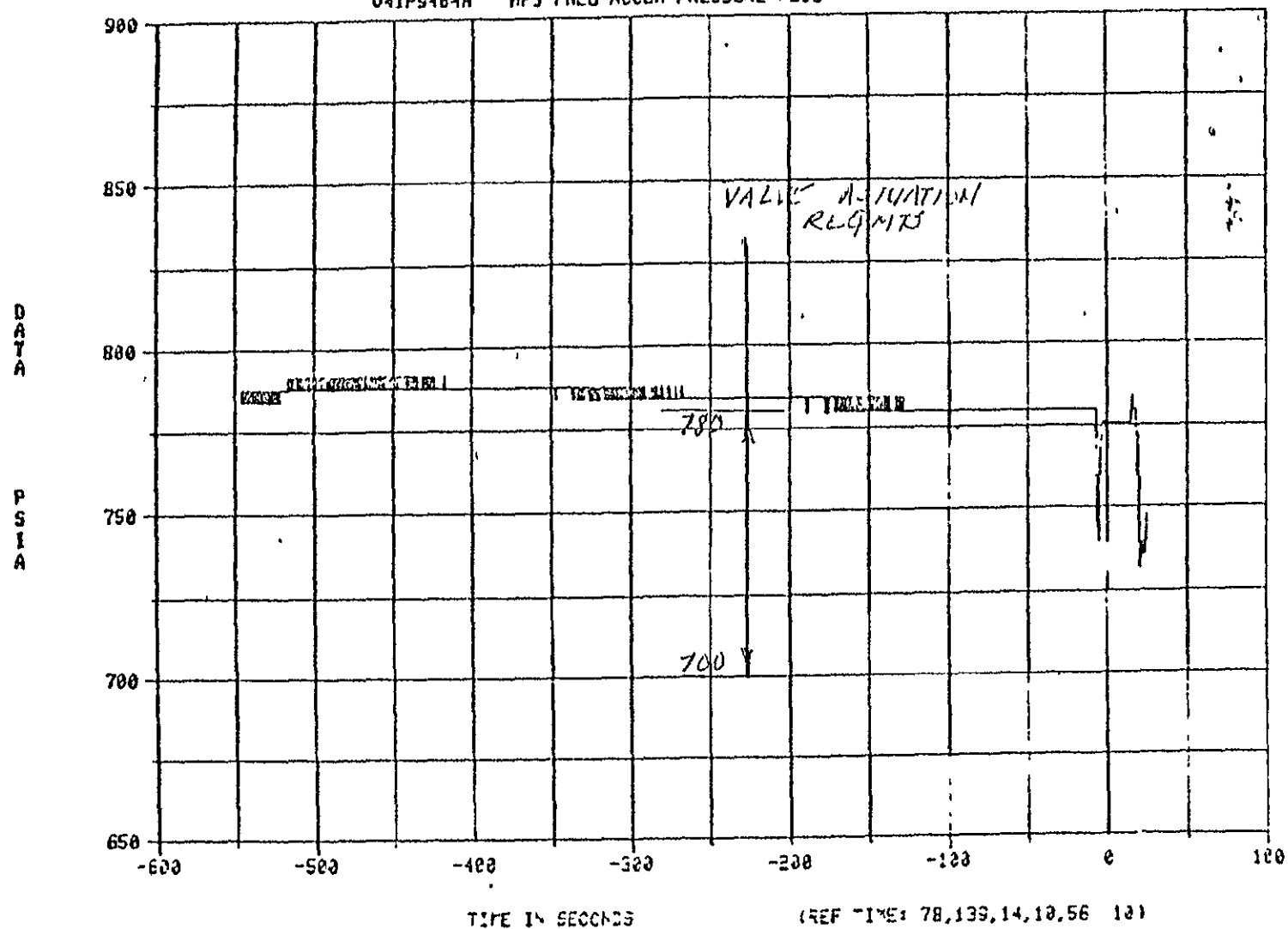
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Figure 4.1 1.5 1-14
V41T9341A MPS ME-3 HE INTERFACE TEMP T206



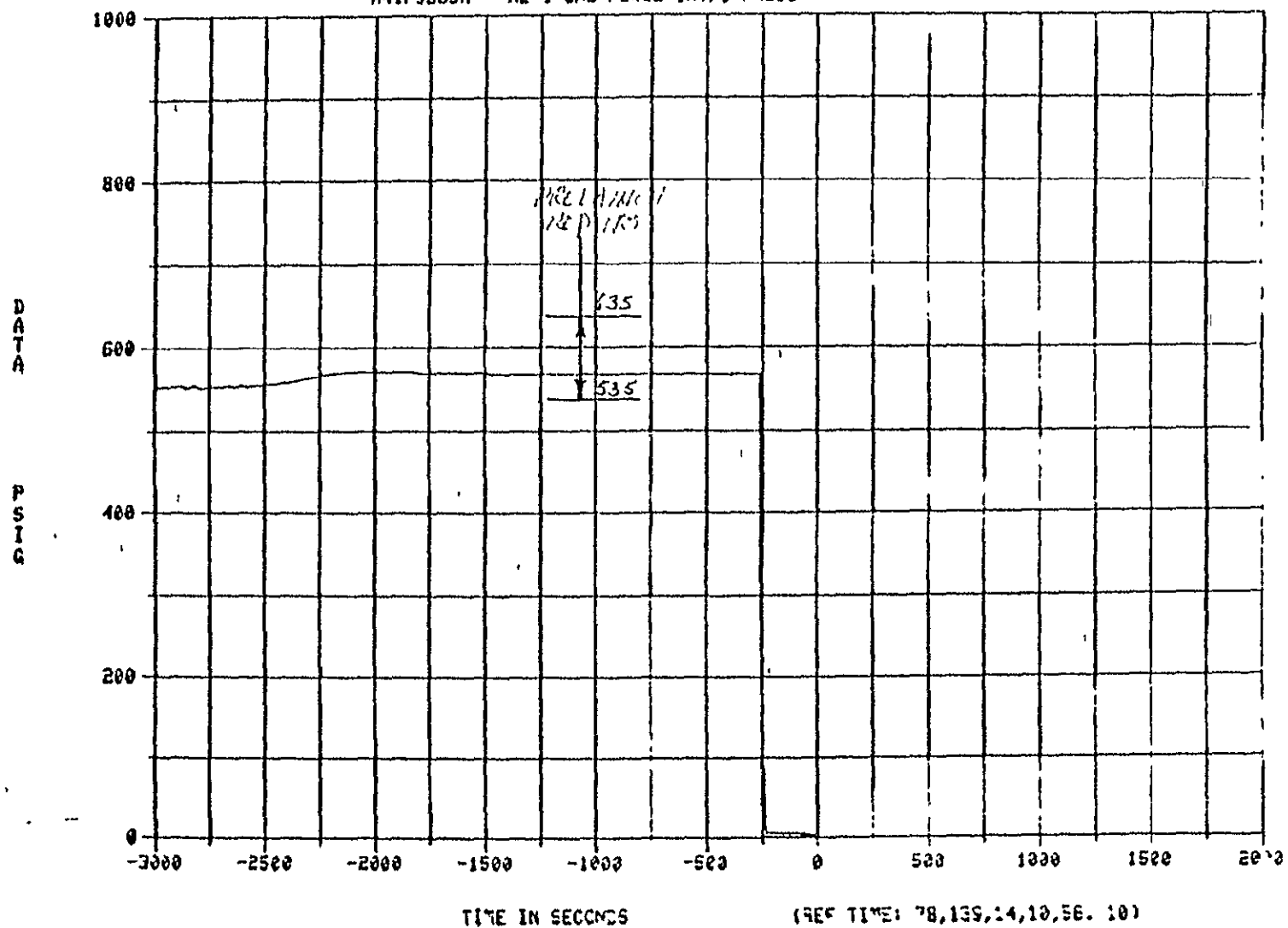
14579

Figure 4.1.1.5.1-15
U41PS484A MFS PNEU ACCUM PRESSURE P203



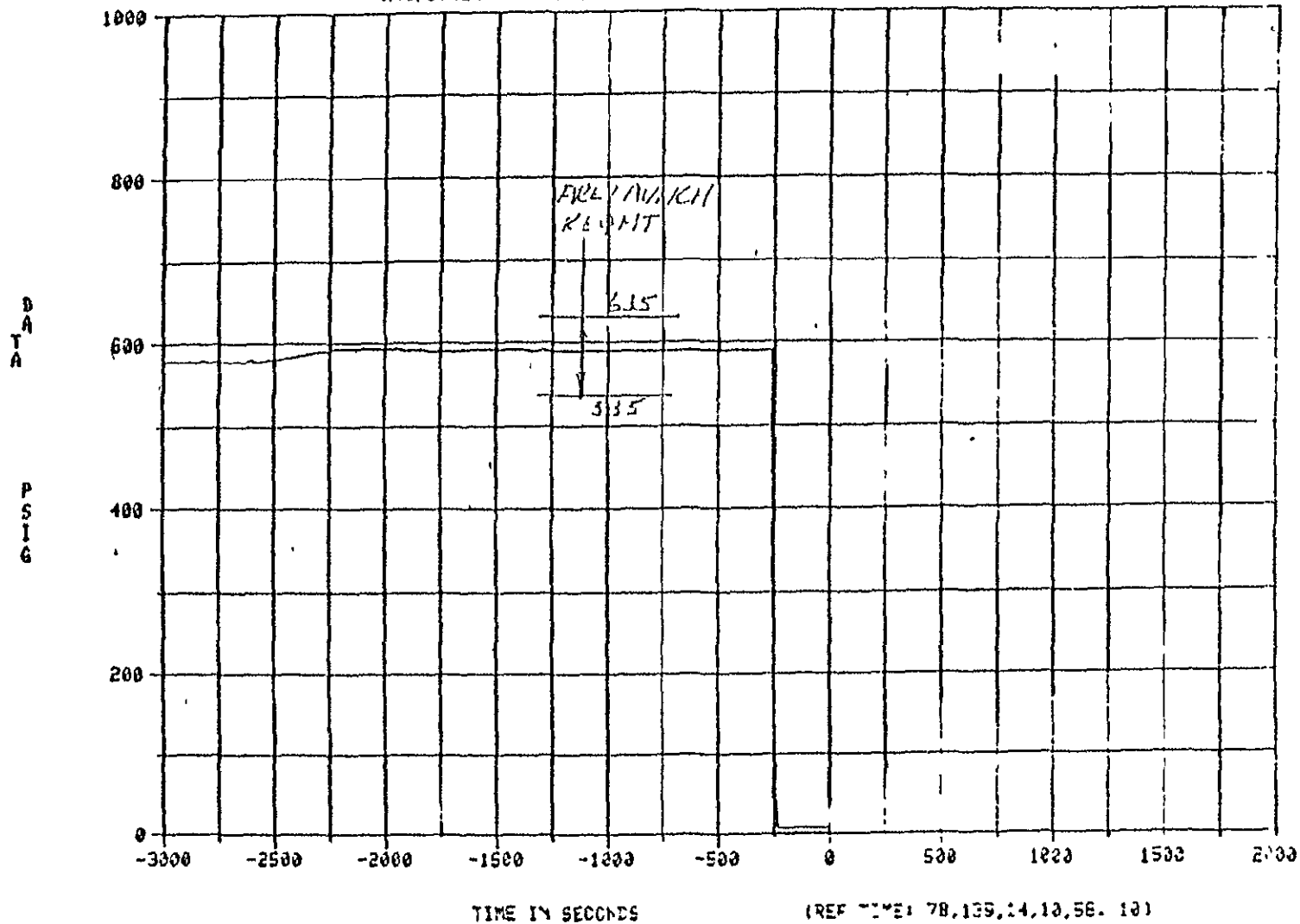
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Figure 4.1.1.5.2-1
A41PS865H ME-1 GN2 PURGE INTFC PRESS



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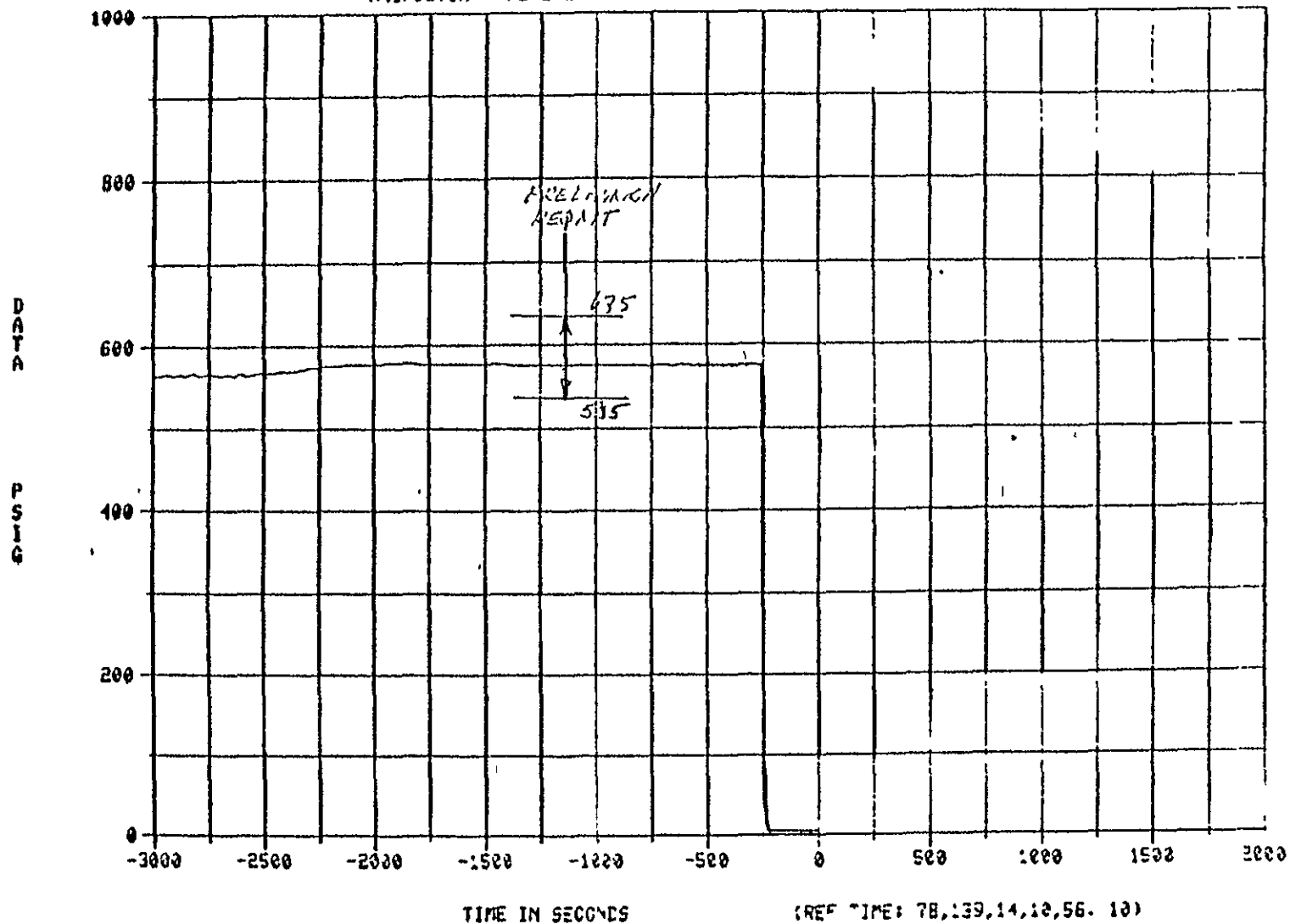
Figure 4.1.1.5.2-2
A41P9868H ME-2 GN2 PURGE INTFC PRESS



14378

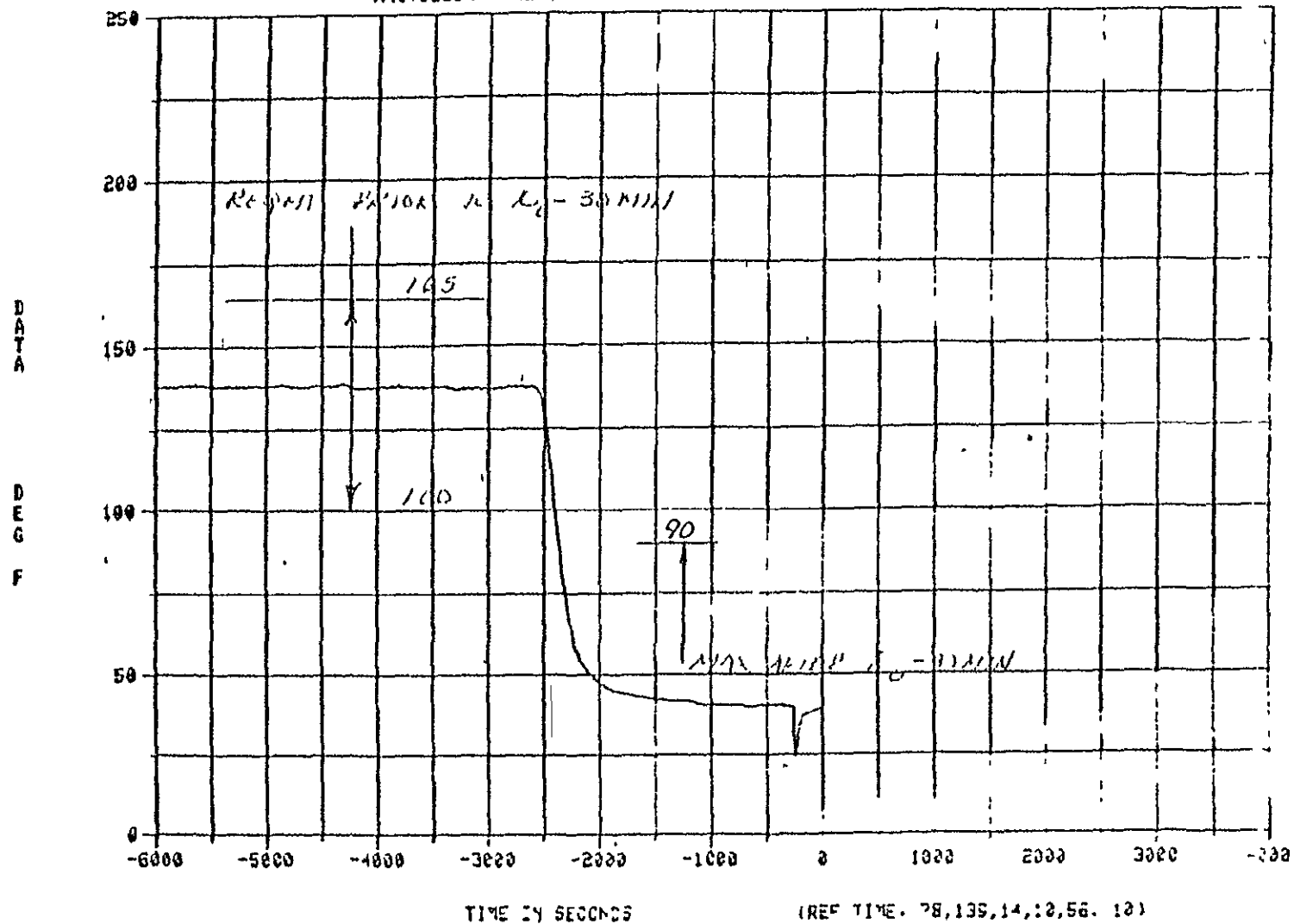
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Figure 4.1.1.5.2-3
A41P0871H ME-3 GN2 PURGE INTFC PRESS



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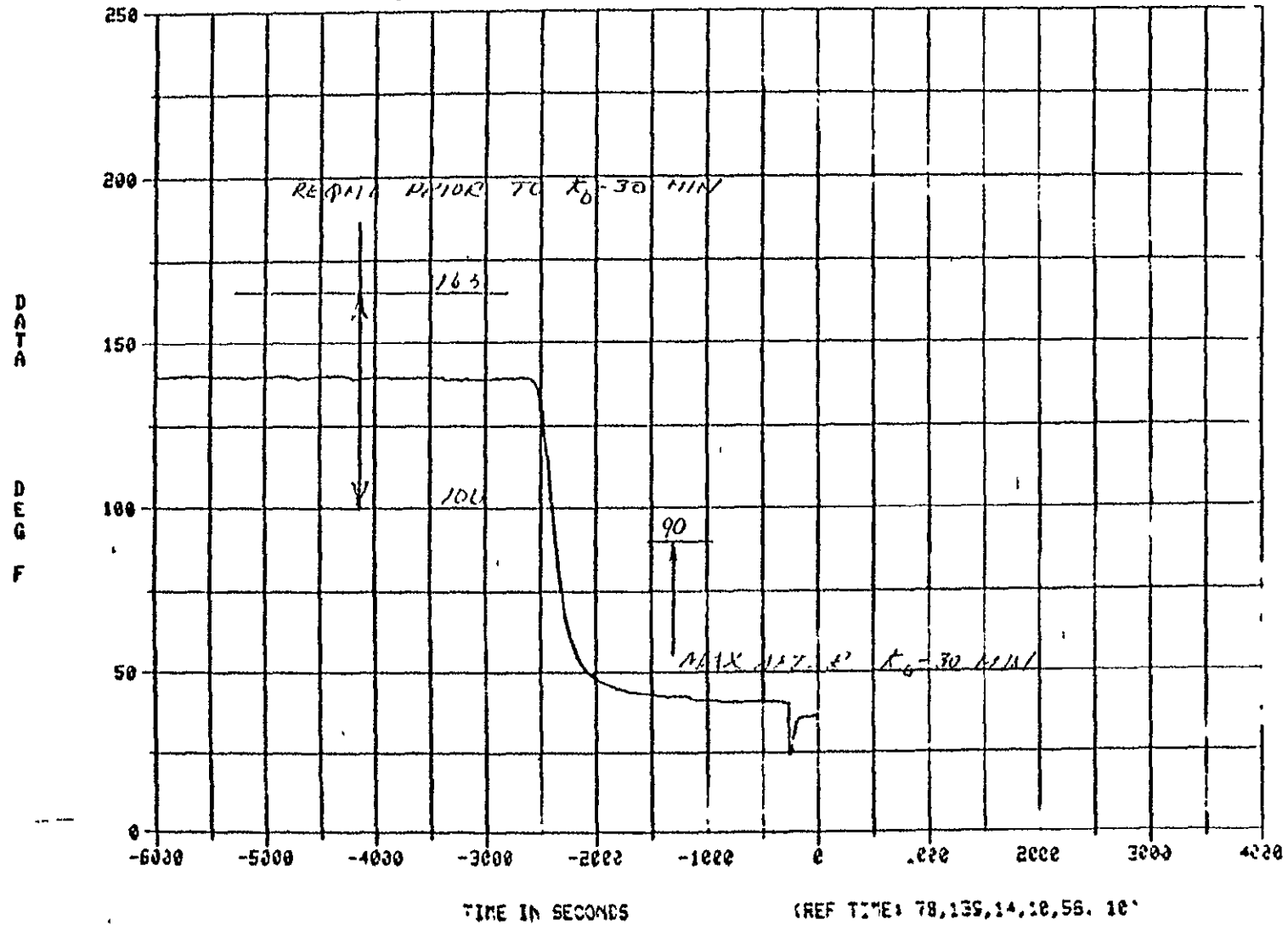
Figure 4.1.1.5.2-4
A4179866H ME-1 GNE PURGE INTFC TEMP



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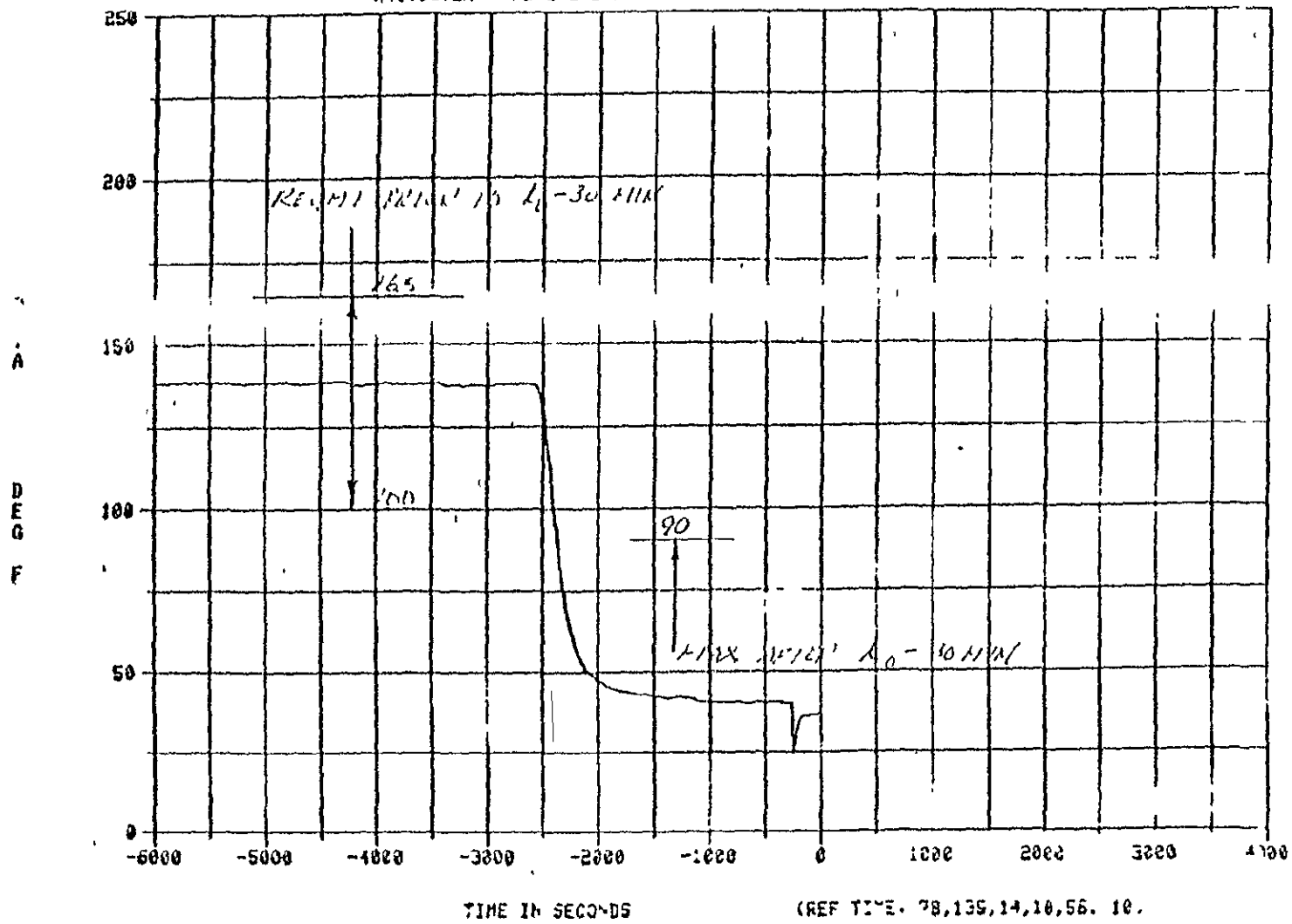
Figure 4.1.1 5.2-5
A41T9869H ME-2 GNE PURGE INTFC TEMP



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Figure 4.1.1.5.2-6
A41T9872H ME-3 GN2 PURGE INTFC TEMP



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4 1.1.6 PERFORMANCE

The operation of the SSME's appeared satisfactory and programmed cutoff's were achieved on all three engines.

| <u>POSITION</u> | <u>ENGINE</u> | <u>DURATION(Seconds)</u> | |
|-----------------|---------------|--------------------------------|-------------------------|
| | | <u>START TO CUTOFF COMMAND</u> | <u>T-ZERO TO CUTOFF</u> |
| 1 | 2001 | 18.85 | 15.10 |
| 2 | 2003 | 20.53 | 16.90 |
| 3 | 2002 | 20.41 | 16.90 |

Figures 4.1.1.6-1 through 4.1.1.6-3 depict the SSME main combustion chamber pressure start buildup profiles to the objective 70 percent power level. Superimposed over the data traces are the ICD buildup envelopes and the proposed revision per IRN 013⁴ to modify the band to be representative of the present engine start sequence. (NOTE: The buildup envelopes are for a start to the 100 percent power level.)

Figures 4.1.1.6-4 through 4.1.1.6-6 present the complete firing chamber pressure data traces. No anomalies were noted.

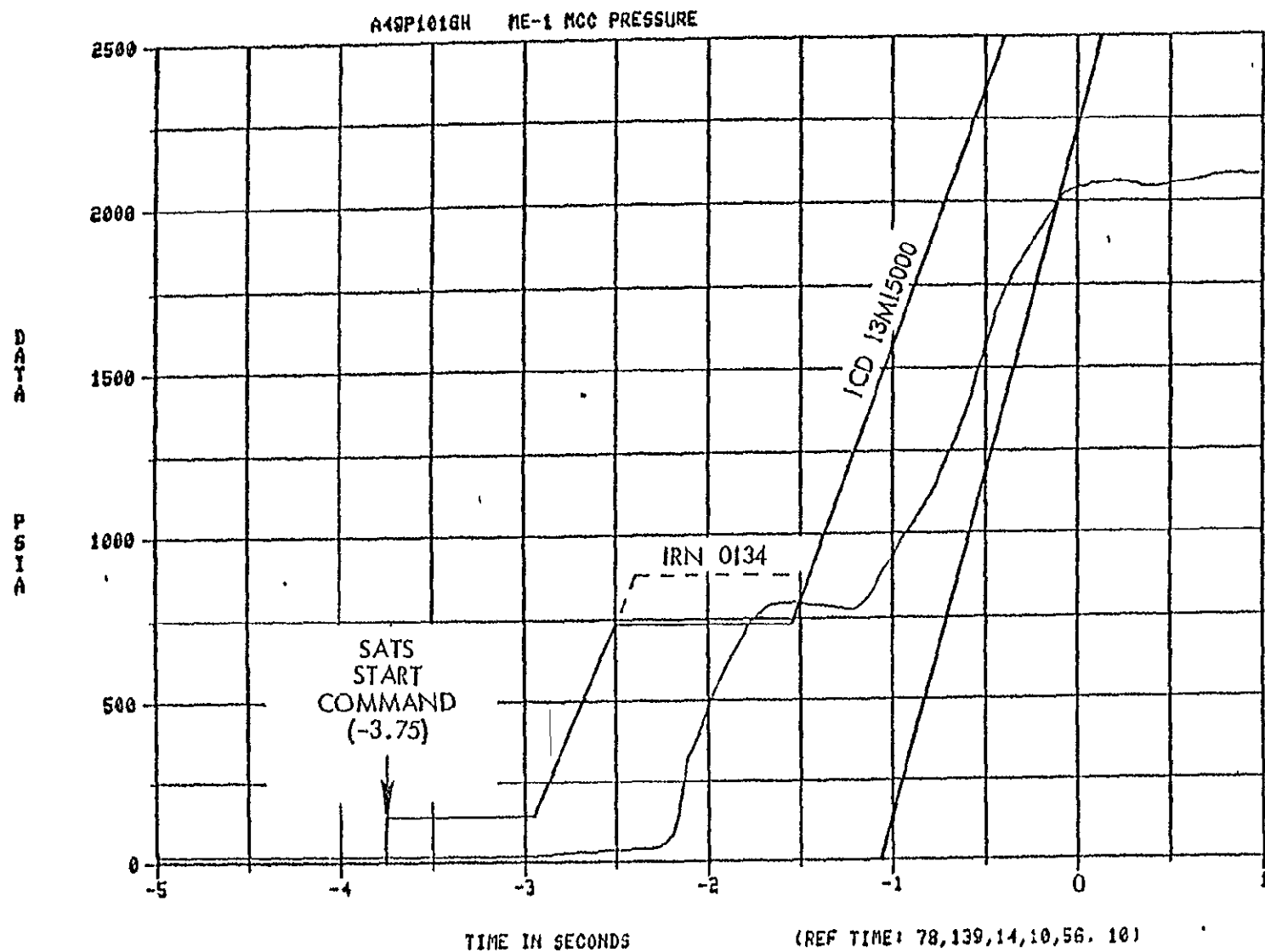
Table 4 1.1.6-1 is a comparison of test data from the MPTA test and the last acceptance test of the particular engines. Although a detail data review has not been completed, there appears to be good correlation and repeatability.

SPACE DIVISION (ROCKWELL)
PROPULSION ANALYSIS GROUP

TEST NUMBER MPT3F2
TEST DATE MAY 19, 1978

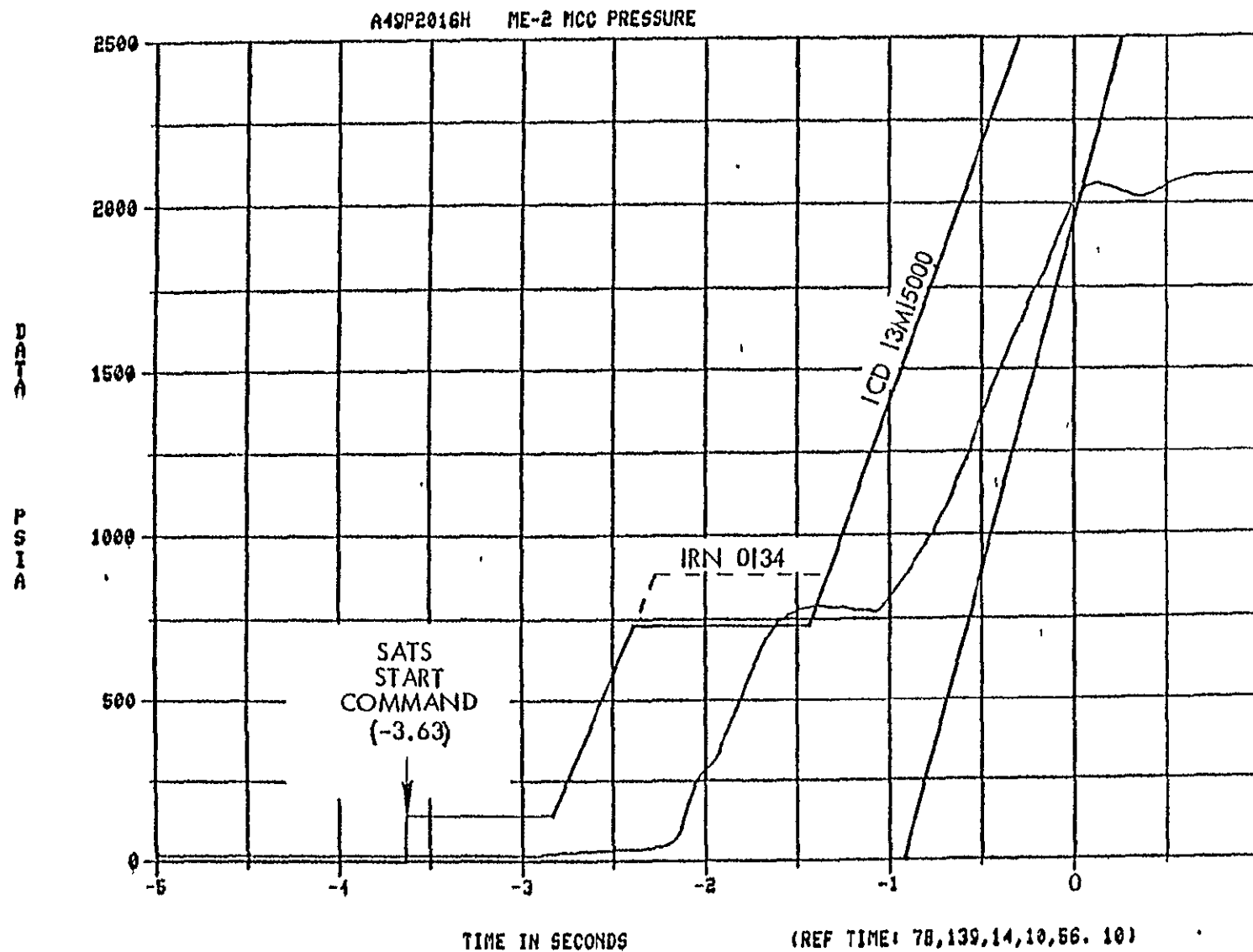
ENGINE: SSME-2001

FIGURE 4.II.G-1



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FIGURE 4116-2



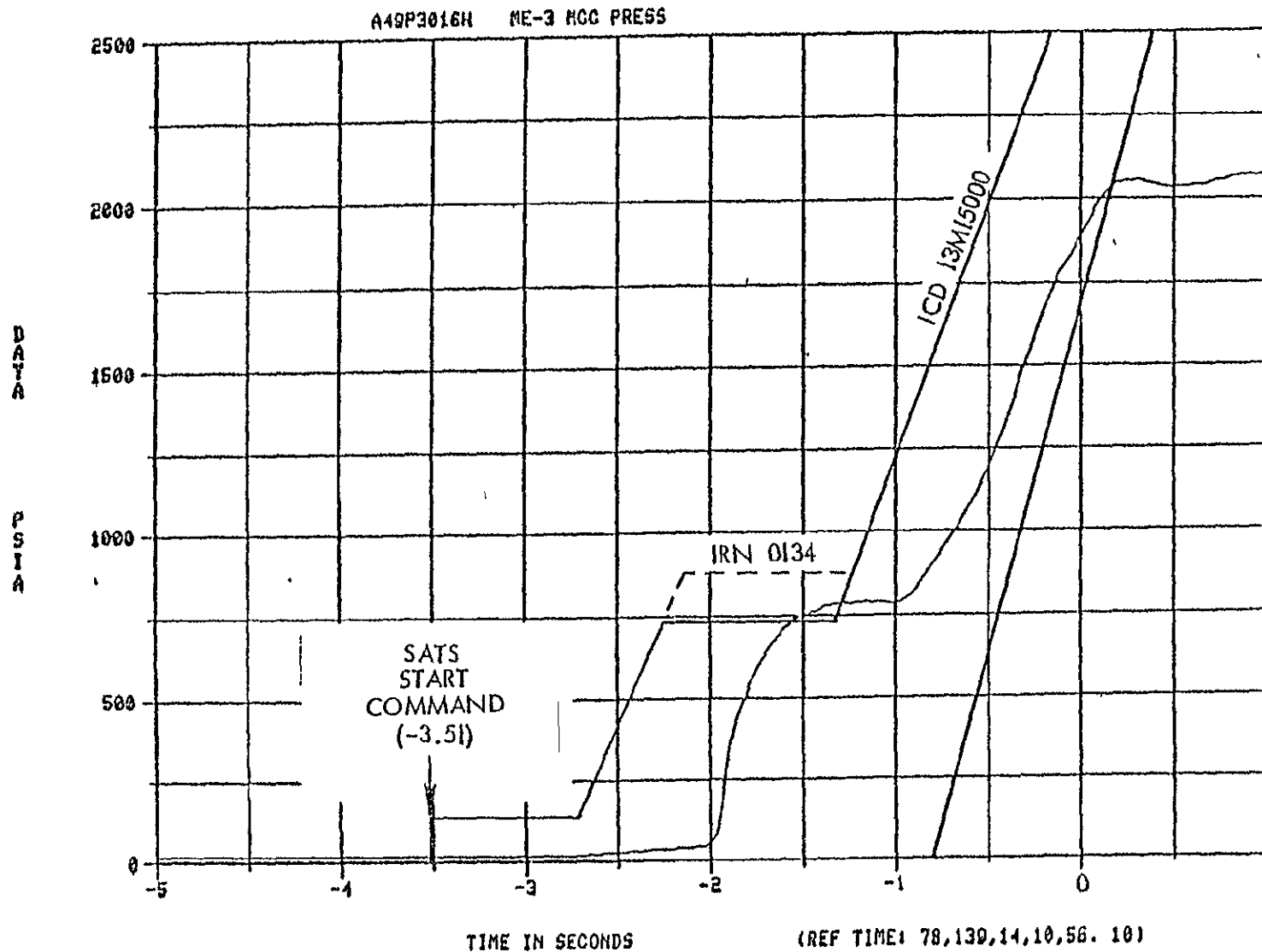
15078

SPACE DIVISION (ROCKWELL)
PROPULSION ANALYSIS GROUP

TEST NUMBER MF15F2
TEST DATE MAY 19, 1978

ENGINE: SSME-2002

FIGURE 4116-3



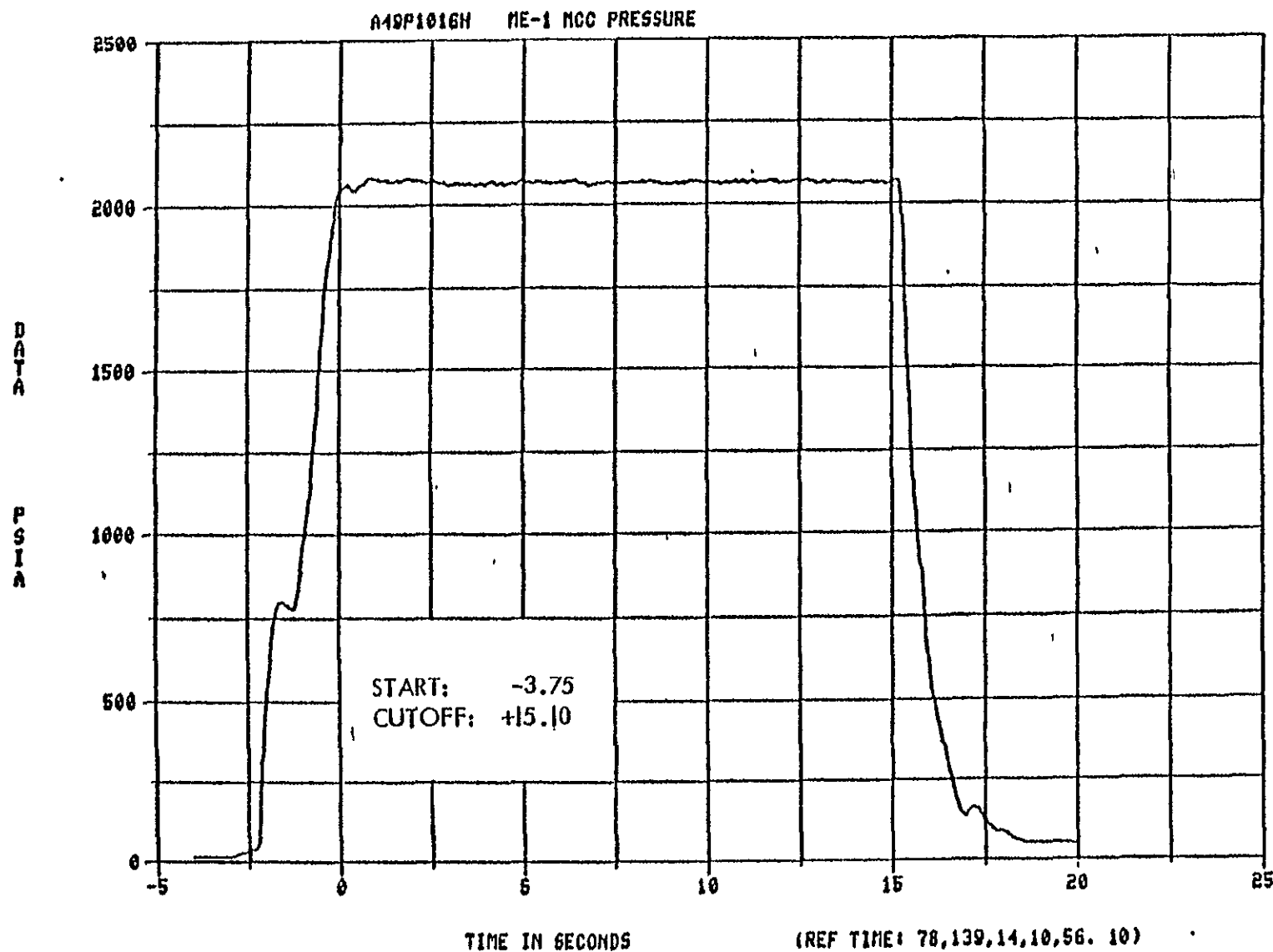
15078

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FIGURE 4.116-4



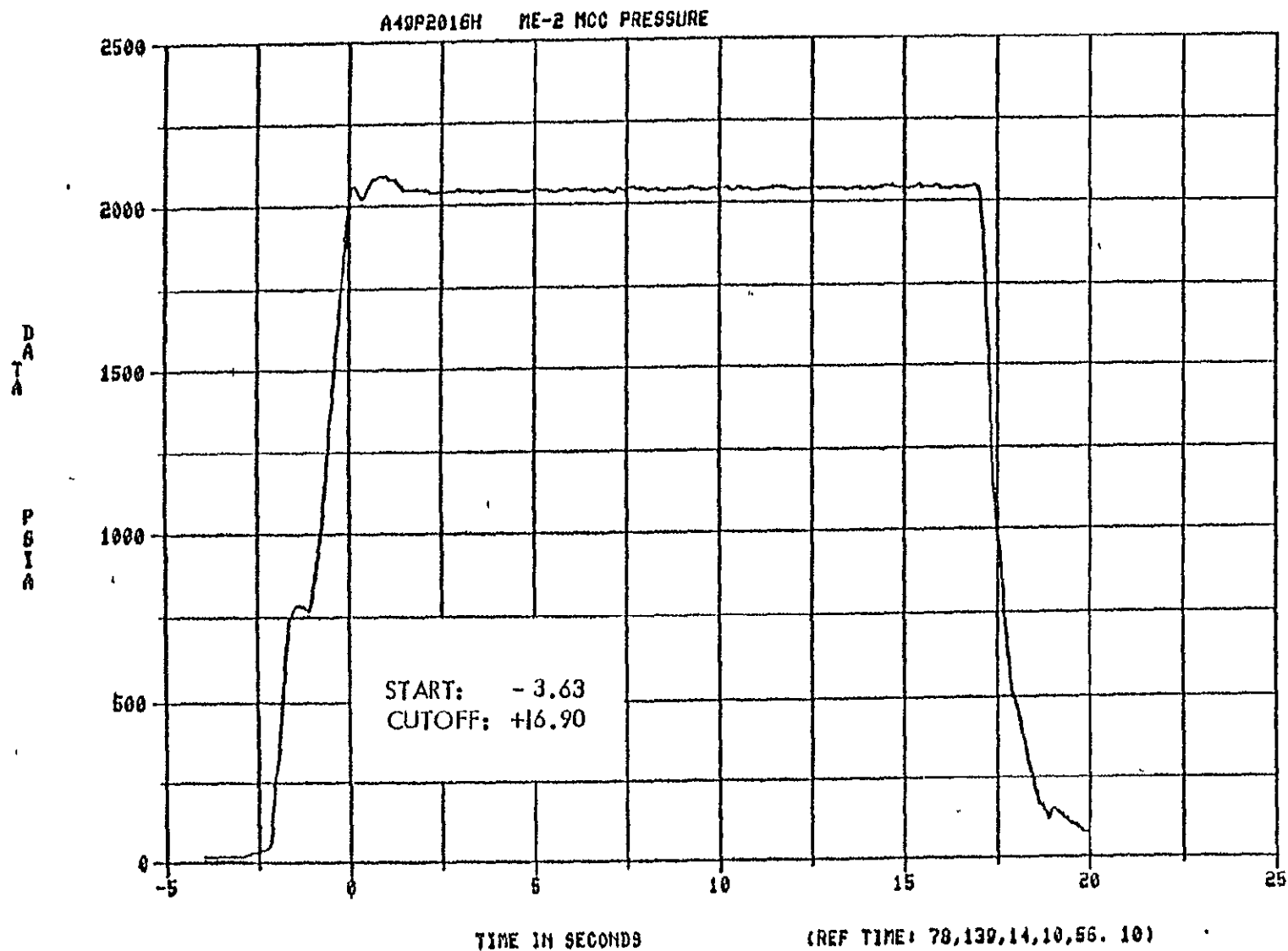
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SPACE DIVISION (ROCKWELL)
PROPULSION ANALYSIS GROUP

TEST NUMBER MFTSF2
TEST DATE MAY 19, 1978

FIGURE 4.11.6-5

ENGINE: SSME-2003

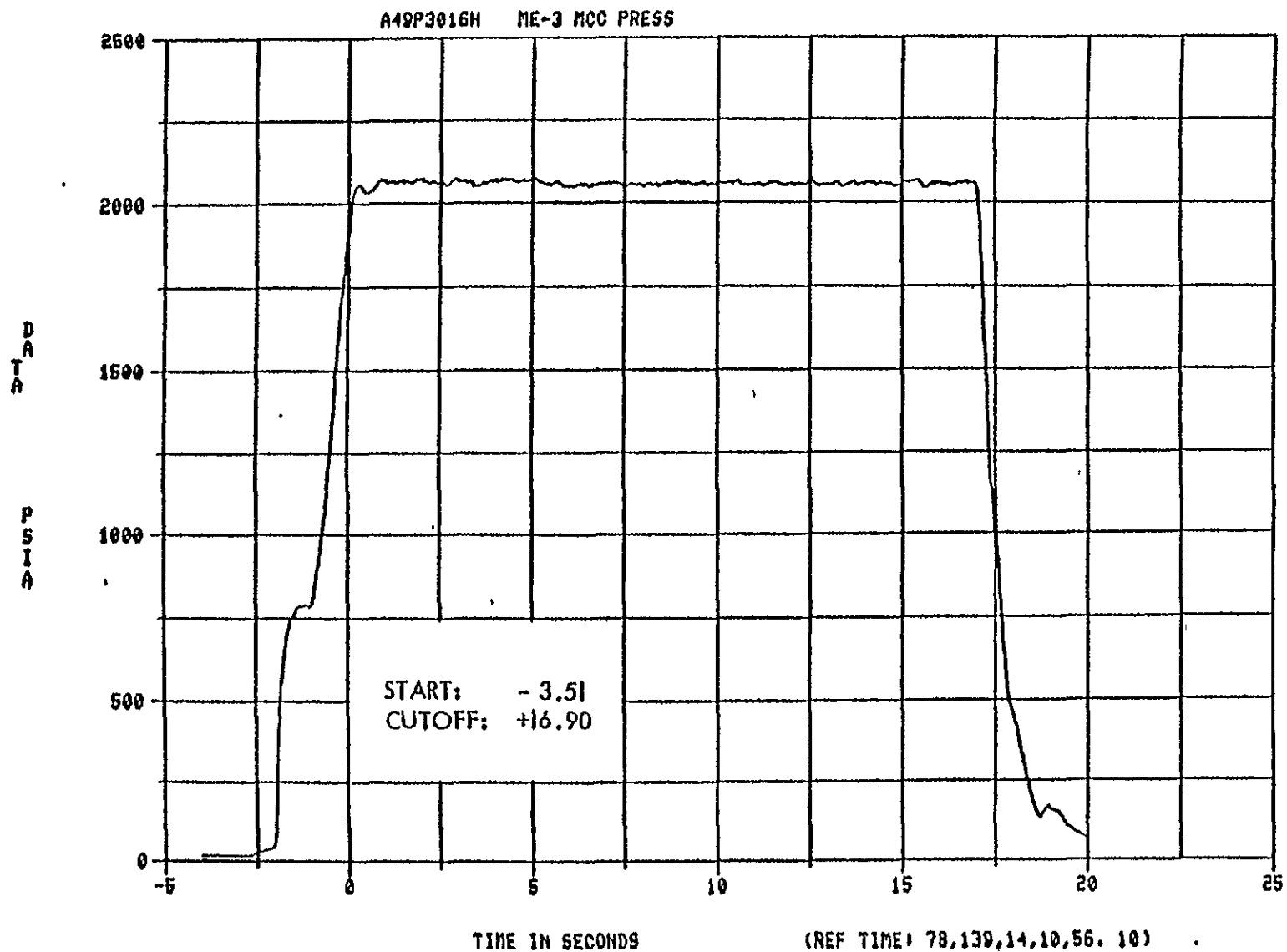


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FIGURE 4.1.6-6



15278

SSME PERFORMANCE

TABLE 4.1.16-1

| Engine | 2001 | 2001 | 2002 | 2002 | 2003 | 2003 |
|------------------------------------|---------|---------|---------|---------|---------|---------|
| Test Facility | SET | MFTA | SET | MFTA | SET | MFTA |
| Test Number | 902-098 | MFT-SF2 | 902-103 | MFT-SF2 | 902-105 | MFT-SF2 |
| Date | 1-25-78 | 5-10-78 | 2-22-78 | 5-10-78 | 3-08-78 | 5-10-78 |
| Slice Time, sec | 65.0 | 14.0 To | 55.0 | 15.9 To | 55.0 | 15.9 To |
| Power Level | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| MCC Pr, psia | 2067.2 | 2060 | 2065.4 | 2060 | 2067.5 | 2040 |
| Oxidizer Flow, GPM | 3075.5 | 3000 | 3910.3 | 3000 | 3540.0 | 3000 |
| Fuel Flow, GPM | 10704.7 | 10500 | 10007.1 | 10520 | 10740.0 | 10650 |
| Oxid Preburner Pr, a | 3090.6 | 3200 | 3098.6 | 3125 | 3099.0 | 3200 |
| HPOT Turbine Temp, R | 1203.0 | 1260 | 1224.9 | 1270 | 1135.2 | 1110 |
| Fuel Preburner Pr, a | 3140.1 | 3250 | 3148.7 | 3250 | 3175.5 | 3250 |
| HPFT Turbine Temp, R | 1542.0 | 1510 | 1615.0 | 1590 | 1746.5 | 1765 |
| LPOT Speed, RPM | 4367.1 | 4225 | 4344.0 | 4280 | 4273.1 | 4200 |
| HPOT Speed, RPM | 21944.4 | 21000 | 21977.6 | 22100 | 21514.5 | 21500 |
| LPFT Speed, RPM | 13311.5 | 13100 | 13267.4 | 14400 | 13974.0 | 13900 |
| HPFT Speed, RPM | 28104.6 | 28500 | 28116.2 | 28000 | 28397.5 | 28500 |
| LPOT Disch Pr, psia | 338.0 | 320 | 335.1 | 342 | 319.8 | 320 |
| HPOT Disch Pr, psia | 3029.0 | 2000 | 3069.0 | 3075 | 2876.0 | 2750 |
| HPOT Disch Temp, R | 183.5 | 190.0 | 183.8 | 183.5 | 182.8 | 181.0 |
| Boost Disch Pr, psia | 5031.2 | 4825 | 5098.9 | 5200 | 4677.6 | 4650 |
| LPFT Disch Pr, psia | 202.8 | 100 | 203.9 | 225 | 218.3 | 212 |
| LPFT Disch Temp, R | 41.3 | 41.0 | 41.5 | 42.2 | 41.7 | 41.9 |
| HPFT Disch Pr, psia | 4120.9 | 3000 | 4106.4 | 4000 | 4123.3 | 4000 |
| MOV Position | 0.903 | 0.91 | 0.900 | 0.91 | 0.902 | 0.91 |
| MFV Position | 0.985 | 0.985 | 0.971 | 1.00 | 0.993 | 1.00 |
| CCV Position | 0.658 | 0.71 | 0.714 | 0.70 | 0.716 | 0.71 |
| OPOV Position | 0.561 | 0.55 | 0.558 | 0.53 | 0.503 | 0.54 |
| FPOV Position | 0.661 | 0.67 | 0.678 | 0.65 | 0.700 | 0.70 |
| INDEPENDENTS | | | | | | |
| Oxid Inlet Pr, psia | 101.8 | 86 | 101.5 | 80 | 101.8 | 80 |
| Oxid Inlet Temp, R | 163.6 | 164.4 | 164.2 | 164.3 | 164.2 | 164.3 |
| Fuel Inlet Pr, psia | 45.7 | 35.0 | 44.2 | NG | 46.2 | 34.5 |
| Fuel Inlet Temp, R | 37.3 | 37.4 | 37.2 | 37.7 | 37.0 | 37.3 |
| Ox Pressurant Pr, psia | | 2610 | 2740.0 | 2520 | 2540.0 | 2610 |
| Ox Pressurant Temp, R | | 735 | 782.0 | 784 | 740.0 | 702 |
| F1 Pressurant Pr, psia | | 2360 | 2260.0 | 2300 | 2310.0 | 2320 |
| F1 Pressurant Temp, R | | 392 | 457.0 | 435 | 467.0 | 440 |
| MISCELLANEOUS | | | | | | |
| NPSP (Oxidizer) | | 60.0 | | 63.0 | | 72.0 |
| NPSP (Fuel) | | 18.0 | | NG | | 17.5 |
| NOTE: All data at SITE CONDITIONS. | | | | | | |



4.1.2 Propulsion Systems - Orbiter

The main propulsion system configuration for Static Firing Number 2 was changed from Static Firing Number 1 as follows:

1. Pneumatic System crossover valves were opened to provide parallel operation of the He storage system.
2. Pre-Valve and Fill and Drain valve thermocouples were moved from the valve actuators to the valve solenoid valves.
3. The Engine #2 -0003 750 psig helium regulator was replaced by a new -0003 regulator and the Engine #3 -0003 750 psig helium regulator was replaced by a new -0004 regulator.
4. The three -0001 LH₂ Recirculation Pump Valves were replaced by -0011 valves.

The Orbiter Main Propulsion system performed satisfactorily throughout the test. System anomalies were minor in nature and did not affect the outcome of the test.

4.1.2.1 Components

4.1.2.1.1 Prevalve Performance. The LO₂ and LH₂ prevalves functioned normally throughout the test.

4.1.2.1.2 Vacuum Jacketed Lines. Performance of all vacuum jacketed lines during the No. 2 static firing test was normal. Vacuum readings taken after the test show that all lines were within specification requirements for vacuum. The FH18 (MC271-0075-0018) line indicated a good vacuum. This was its first vacuum reading, after having been evacuated following the first static firing. Additional vacuum readings will be necessary before a decay trend can be established for this line.

Vacuum jacket surface temperatures which are monitored on lines selected as representative of other vacuum jacketed lines were at their expected temperature. LO₂ feedline (MC271-0074-0103) surface temperature was the coldest at -20F. However, this MPTA-Only line has a heat short close to the sensor. The sensor was moved to this location prior to the second firing from a location directly on the heat short where it indicated a -60F temperature during the first firing.



- 4.1.2.1.3 Feedline Inlet Pressure Transducers. LH₂ and LO₂ Main Engine Number 3 feedline inlet pressure transducers, V41P9396A and V41P9395A, showed lower than normal pressure readings during engine operation when compared with normal pressure readings on engines 1 and 2. This condition was expected to occur as the transducers on engines number 1 and 2 were insulated and the transducer on Engine #3 inlet was not. This characteristic is caused by calibration shifts resulting from thermal gradients within the transducer. It is recommended that the Main Engine #3 transducer be insulated.

The pressure on the main engine #3 LH₂ inlet pressure transducer went off scale high approximately 13.6 seconds after T₀. The engine number 1 and number 2 LH₂ inlet pressures were normal throughout the test firing. It is probable that there is an open circuit in the transducer bridge. It is recommended that the transducer be tested to determine failure mode and replaced if defective.

- 4.1.2.1.4 Point Sensors. Review of test data from the Rockwell procured point sensor transducers (ET and Orbiter) and (ET and Orbiter) point sensor electronics boxes indicates that they operated properly except for the following:

The ET LOX point sensors 4, 3, 2 and 1%, measurement numbers A48X9860W, A48X9861W, A48X9862W and A48X9863W were reported by MMC to stay in the dry mode during the tanking. MMC and Rockwell are now troubleshooting the problem.

LOX low level point sensors 1 and 3, measurement numbers V41X1555X and V41X1557X, have a zero volts dc output signal during the whole test which is an indication of oad data or an open sensor circuit. However, an observer on the loading display panel reports that lights for these sensors indicated that they were functional.

- 4.1.2.1.5 Temperature Measurement. The surface temperature sensors for measurements A41T9487H for the fill and drain valve and A41T9488H for the pre valve were reported to be incorrectly installed during static firing number one. This condition was corrected for the second static firing as indicated by the temperatures recorded during static firing number two. The solenoid temperatures were as high as 280°F prior to servicing. Following introduction of LH₂; the fill and drain valve temperature was reduced to as low as -50°F and the pre valve temperature was reduced to as low as -20°F. These values are acceptable.



4.1.2.1.6 LH₂ Recirculating Pumps. The performance of the recirculating pumps during static firing number two was in accordance with the specification except during the T_O-18400 to T_O-16800 time period. (Transition from LH₂ tanking fast flow to topping). Two irregularities were noted during this period. One was a spike in the pump differential pressure (approx. 12 psi) occurring at approximately T_O-18300 and the other was pump cavitation occurring intermittently during the aforementioned time span. These two anomalies were typical for all three pumps. The pump differential pressures (P701, P702 & P703), LH₂ inlet pressure at the orbiter interface (P228) and valve position data were analyzed to determine the cause of the anomalies. Although some of the data were questionable, the following conclusions were drawn.

The spike in the pump differential pressure was caused by the sequence of operation of the facility valves during the transition from fast fill to topping. Incorrect sequence of the facility valves will overload the vehicle recirculation-replenish line thus causing the recirculating pump to work against excessive back pressure resulting in a higher than normal differential or pump outlet pressure. Figure 4.2.1-1 shows the positions of the valves during the time in question. At the time of the spike MV101 is closed and subsequently opened. This condition will overload the vehicle replenish line. However, the spike lasted for only 100 seconds because the facility cool down valve (TCV106) was opened and relieved the pressure.

The pump cavitation was caused by the presence of hydrogen vapor at the suction side of the pump resulting from the blockage of the high point bleed line. The high point bleed line and the facility cool down line discharge into a common pipe in the hydrogen vent system to the burn stack. During the time the high point bleed was venting into the common pipe the facility chill down valve (TCV106) was opened discharging sufficient hydrogen into the common pipe to cause a back pressure on the high point bleed line.

It is recommended:

1. A separate line discharging directly into the H₂ vent line to the burn stack be provided for the high point bleed.
2. The sequence of the facility valve operation during the transition from fast fill to topping be investigated.
3. The validity of the discrettes for the concerned facility valve positions be verified.



4.1.2.2 Feed System

- 4.1.2.2.1 Differential Pressure Propellant Monitoring System. The differential Pressure Propellant Monitoring System (measurements V41P1464A(LH₂) and V41P1564A(LO₂) is operating satisfactorily and essentially the same as on static firing #1. Proper full tank pressure levels of 2.63 PSID versus 2.7 PSID (predicted) for LH₂ and 67.5 PSID versus 65.8 PSID predicted for LO₂ were achieved. Accuracy at these valves for a full tank were within 1.0% (LH₂) and 2.6% (LO₂) versus the 4% requirement.

The output signals still exhibit the slow oscillations that were experienced on the first static firing. The oscillations were about 200 to 250 Mv (peak to peak) at 0.04 Hz with secondary oscillations of 50 Mv (peak to peak) at 1 Hz. This problem has not occurred on other ΔP signal conditioners during development and qualification tests which included satisfactory completion of an EMI test. These considerations and the unlikely probability that a fluid problem would create synchronized signals in both tanks indicates an electrical problem exists outside of the ΔP system. NSTL is now investigating this problem.

- 4.1.2.2.2 Ullage Pressure Control System. All orbiter components of the ullage pressure control system operated satisfactorily. The problem with the LH₂ ullage pressure transducers encountered on the first static firing did not reoccur. During tanking, auto-sequence and detanking, the ORB ullage pressure signal conditioner and ET transducers properly indicated the ullage pressure with close agreement on all readings. The ORB ullage pressure signal conditioners also issued the appropriate flow control valve command signals during autosequence and during the static firing with no problems.

4.1.2.3 Pneumatic System

- 4.1.2.3.1 MPS Pneumatic Supply System. The crossover valves were opened approximately 30 minutes prior to T₀ which causes parallel operation of the pneumatic supply system and regulators. At this time the Engine #2 regulator outlet pressure indicated approximately 812 psia and it continued to indicate this pressure except during purge sequence 4 when it dropped to 776 psia. After purge sequence 4 it again increased to an indicated 812 psia until the crossover valves were closed.

Examination of the engine supply pressures shows that except during periods of high helium demand the engine one helium regulator supplied the helium requirements. This is a feature of parallel mounted regulators in which the regulator with the highest output pressure will supply output flow until its output can no longer supply demand. This is shown by examining supply pressure decay as seen in Figure 4.1.2-2 where the supply pressure of engine one drops while the other supply pressures remain high. When the purge sequence starts, helium supply pressures all drop.



The pressure measurements given by the data are all within the tolerance of the gage readings and as a consequence cannot be used to definitely determine the actual performance of the system on a comparative basis. Examination of Figure 4.1.2-3 shows the outlet pressure of the engine two regulator to have a higher output pressure than the engine number one regulator. This leads to the erroneous conclusion that the engine two regulator supplies the helium.

The pneumatic helium system with parallel mounted regulators is performing as expected.

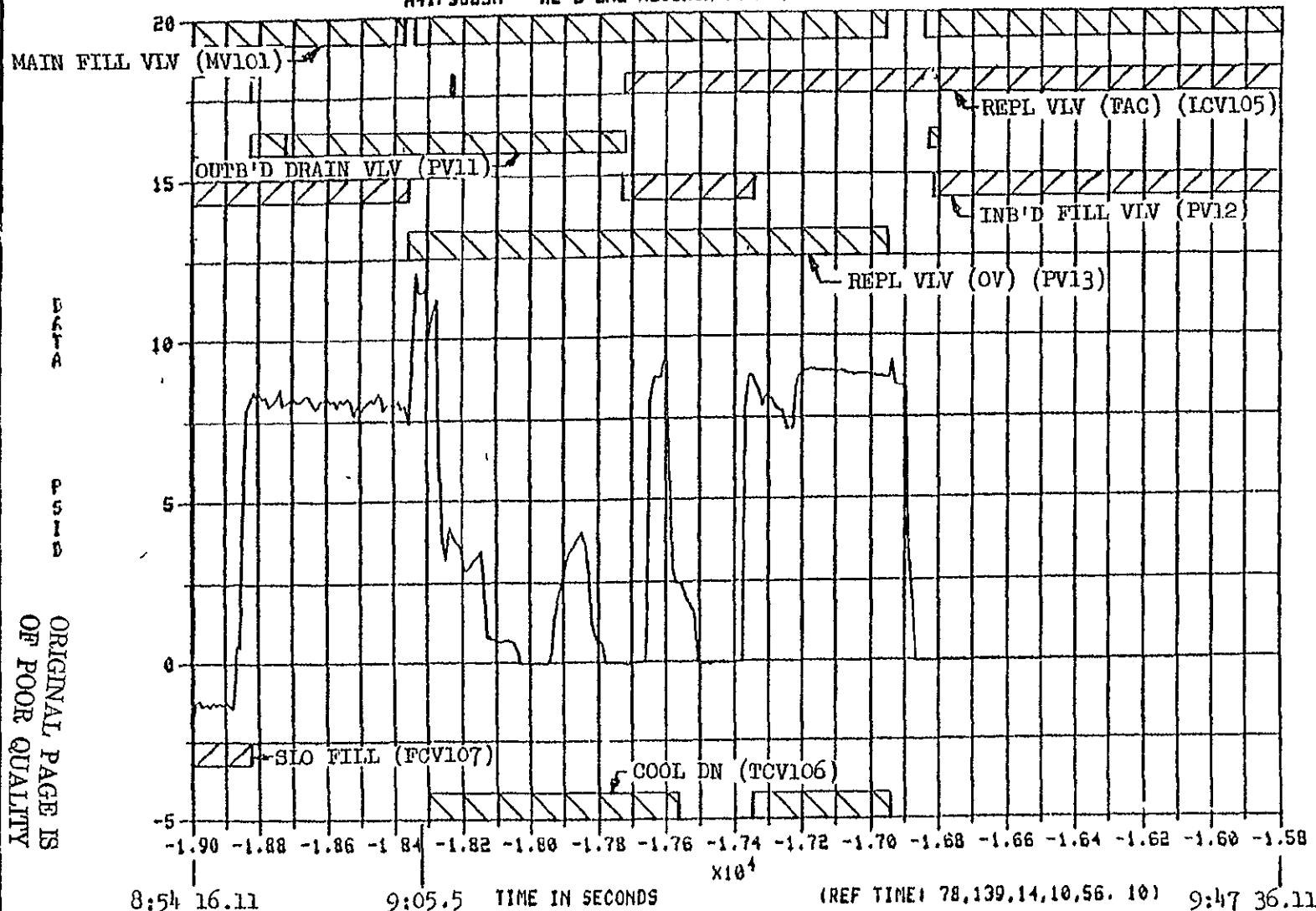
It is recommended that an end to end calibration be performed on all pneumatic system transducers.

TEST NUMBER MPTSF2
TEST DATE MAY 19, 1978

CODE:

 VALVE OPEN

A41P9863H ME-3 LH2 RECIRC PUMP DPRESS



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FIGURE 4.2.1-1

SD78-SH-0125

HELIUM SUPPLY PRESSURES

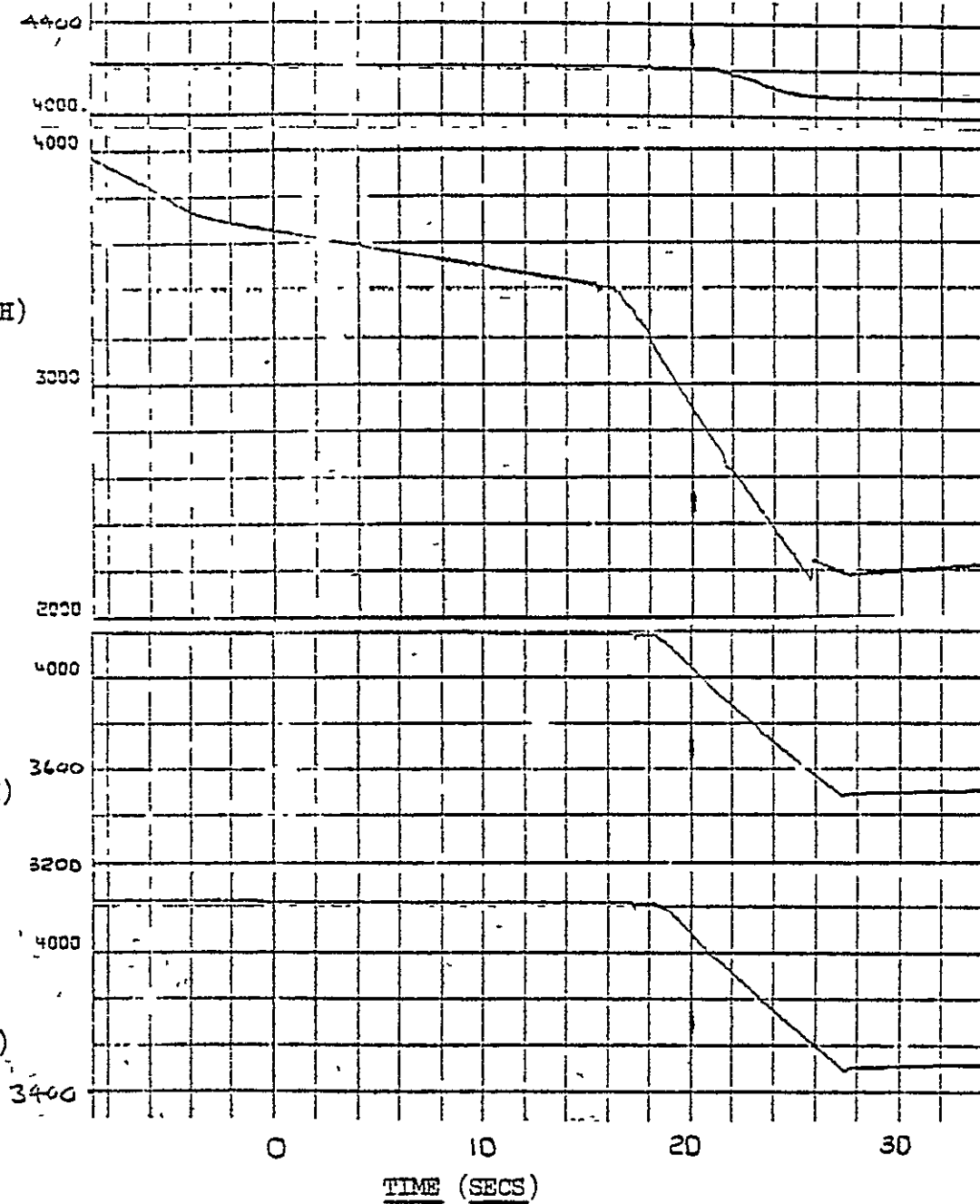
MPS PNEU SUPPLY
(V41P160CH) ---

ENG #1 He
SUPPLY
(V41P1150H)

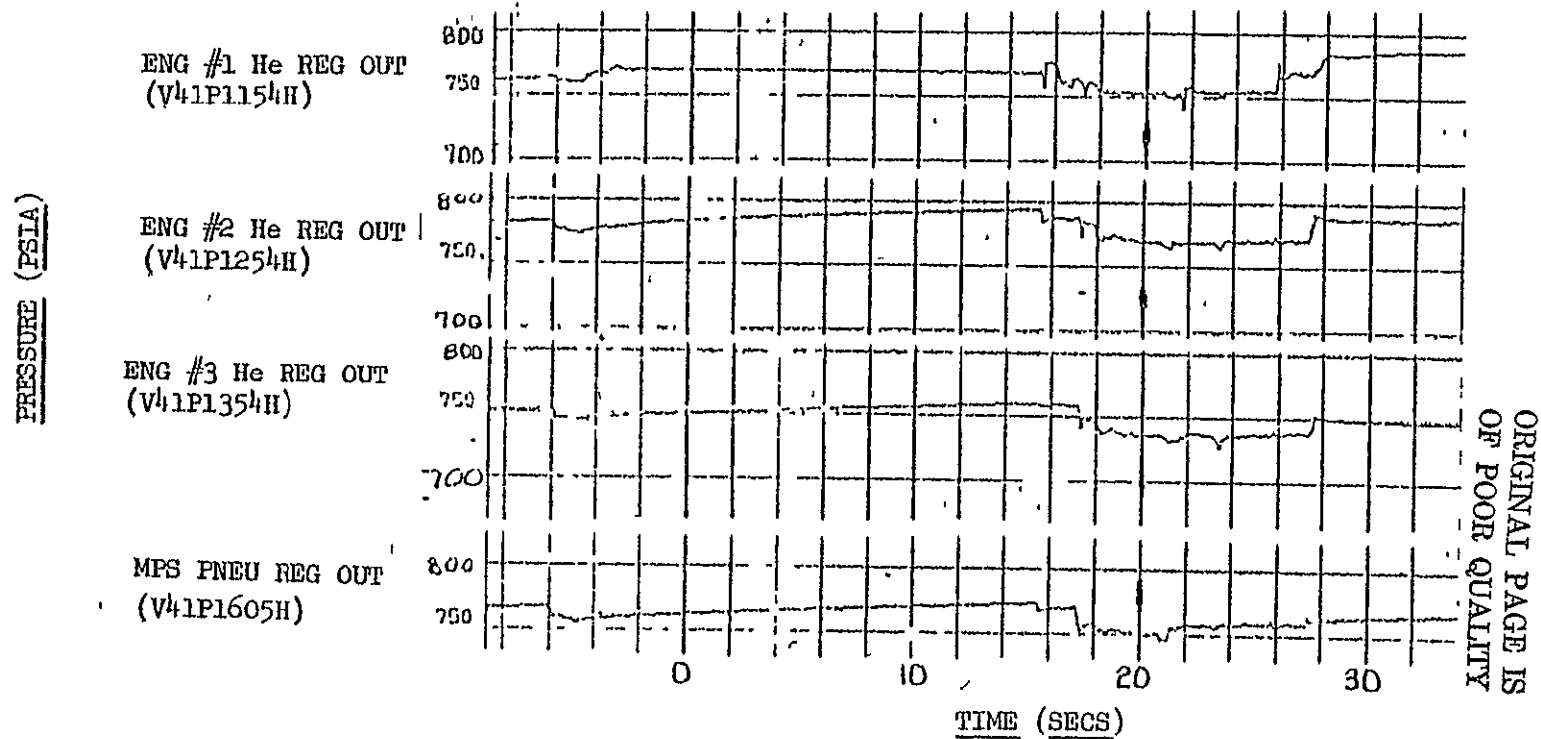
ENG #2 He
SUPPLY
(V41P1250H)

ENG #3 He
SUPPLY
(V41P1350H)

PRESSURE (PSIA)



ENGINE HELIUM REGULATOR OUTLET PRESSURES





4.1.3 PROPULSION SYSTEMS - ET

4.1.3.1 Propellant Loading

Tanking and detanking was successfully accomplished.

Maximum Fast Fill Temperatures ($^{\circ}\text{F}$)

| | ICD | Observed |
|-----------------|------|----------|
| LH ₂ | -422 | - -422 |
| LO ₂ | -290 | -292 |

Fast Fill Flowrates (GPM)

| | ICD | Observed |
|-----------------|---------------|----------|
| LH ₂ | 10,170-12,000 | 12,900 |
| LO ₂ | 4,420 - 4,980 | 3,600 |

The maximum ullage pressure observed during loading was 6.7 psig for GH₂ and 2.6 psig for GO₂.

4.1.3.2 Anti-geysering

The Anti-geyser System performed as expected and met all ICD requirements.

4.1.3.3 Pressurization

The observed ullage pre-pressurization rise rates were less than predicted.

Ullage Rise Rates (psi/sec)

| | Predicted | Observed |
|-----------------|-----------|----------|
| GH ₂ | 1.9 | 1.2 |
| GO ₂ | 1.6 | 1.1 |

Ullage volumes and pre-pressurization flow rates are being evaluated to explain the predicted/observed deviations.



4.1.3.4 Components

The LO₂ diffuser was bore scoped. Flaw-like suspects were noted around the periphery of some of the vent noles. The diffuser will be removed and replaced with a like item.

The LH₂ diffuser will be removed and replaced with a heavier walled configuration. The flight unit removed will be inspected.

The Teflon gasket under the LO₂ vent orifice leaked. The orifice design is being modified to show serrations in the vicinity of the seal.

The 3.7 in. diameter LO₂ vent orifice is being replaced with a 3.5 in. dia. orifice. The 3.5 in. dia. orifice will be located to clear the ullage pressure sense port.



4.1.4 Propulsion System - SSME

Propellant Load and Chardown

Propellant load and SSME chardown were satisfactorily accomplished without incident. Main Engine Position No. 2 Main Fuel Valve hydraulic warmant return fluid again displayed the lowest temperature of the three SSME's showing a minimum of -4°F . It is significant that a stabilizing trend was indicated during the latter minutes of chardown prior to increasing SSME hydraulic supply pressure. Since SSME hydraulic standby recirculation differential pressure was essentially equal to that of the preceding tests, the stabilizing trend may be attributed to operating at an increased SSME hydraulic supply temperature of 10 to 15°F .

Attempt to obtain more predictable results for the SSME Heat Shield Support Ring temperature measurements was only partially successful. Although insulation of LH2 system temperature sensors in the proximity of the support ring thermocouples was accomplished, the No. 2 SSME position measurements gave erratic results and will require further corrective action before the measurement can be considered acceptable as a redline parameter.

Auto-Sequence and Start

SSME responses through auto-sequence and start appeared normal in all respects. No Engine Start Enable inhibits were displayed and therefore no rollback or resume options were implemented. Key engine start plateau parameters were well within expected range indicating good response to pre-test adjustments made to oxidizer preburner oxidizer valve open loop command position. Accordingly, all critical start plateau performance parameters were on predicted target values. Other SSME control logic changes made to accommodate the seventy percent start and to optimize start performance produced predictable and expected results.

SSME Mainstage and Shutdown

Steady-state, SSME mainstage, site performance was within predicted range and provided acceptable margin when compared to nominal seventy percent control limits. No anomalous performance/operational characteristics were observed.

The SSME proceeded through programmed duration and shutdown as commanded by SATS. Shutdown characteristics were satisfactory depicting nominal engine MCC pressure and turbopump speed decay times and rates.



4.1.4 (continued)

Post Shutdown

Post shutdown observations revealed considerable residual after burning from about the nozzle exit plane of the SSME's. Hardware examination confirmed that the No. 2 position SSME nozzle had been subjected to considerable overheating as indicated by a pattern of discoloration, most pronounced on the inside nozzle wall. Post-test data evaluation revealed evidence that substantial LH2 leakage existed past the SSME, Position No. 2, Main Fuel Valve after shutdown and continued during the detanking time phase for a duration greater than 6,000 seconds. Reason for the leakage from the MFV could not be determined after removal and checkout at Rocketdyne. No valve defects were found that would result in such leakage. Further evaluation will be made and safeguards to minimize the effects, should another similar incident occur, will be established. Materials analysis revealed that no degradation (structural material properties) occurred and the nozzle is suitable for further testing.



4.2 AVIONICS SYSTEMS

4.2.1 Electrical Power, Distribution and Control (EPDC)

The EPDC system performed satisfactorily during Static Firing Test SF-002.

4.2.2 Instrumentation

4.2.2.1 Orbiter Instrumentation

The orbiter instrumentation equipment includes transducers, signal conditioners, the PCM Master Unit and frequency division multiplexers (FDM's).

No anomalies were observed in the Flight Instrumentation PCM System. One pressure transducer failed (Engine 3 LH2 pump inlet) and has been replaced.

The DFI Wideband Measurement System experienced a high percentage of anomalous measurements. Some (45) data squawks were submitted against (120) wideband measurements as follows: 7 (HFA accelerometers), (34) LFA accelerometers (POGO) and (4) acoustics. The data squawks identify the following types of measurement anomalies: erratic data, no data signal, clipped data, and bias shift. The reasons for the problems which resulted in these measurement anomalies will be identified and resolved as the individual data squawks are worked by the Rockwell Instrumentation groups at Downey and NSTL.



4.2.2.2 Instrumentation - ET

ET OI

No OI instrumentation was lost during the firing. One (1) discrepancy reported a ground computer error.

ET DFI

PCM operation was satisfactory.

Nine (9) instrumentation discrepancies were reported of which five (5) were noisy but had recoverable data for the majority of the firing.

FDM operation was satisfactory.

Noisy FDM operation experienced prior to SF2 was corrected by terminating FDM signal returns to ET ground.

Three (3) of thirty (30) high frequency channels had questionable data. All acoustic data was good. Two (2) of twenty-five (25) POGO channels had questionable data.

ET DTI

Overall the DTI instrumentation functioned satisfactorily.

Nine (9) instrumentation discrepancies were reported. Five (5) were POGO data and four (4) were temperature data.

4.2.2.3 SSME Instrumentation

No anomalies were observed. Rocketdyne considers system performance to be highly successful for this stage in the program.



4.2.2.4 GTI/DTI

Test MPT-S2-001

There were a total of 855 measurements recorded on the GTI/DTI system (555 on Beckman, 186 on CBW, 114 on High Freq). A total number of 106 data squawks were written by the data evaluators. Five measurements were identified bad prior to test, 24 required changes to the MSI file for Slidell processing, and three required software changes. Therefore, 32 of the 106 data squawks can be classified as invalid from the standpoint of the instrumentation systems. Another 35 squawks pertain to a common problem on the CBW recorders and appear to be in the processing or recording procedure. The remaining 39 squawks are presently under investigation.



4.2.3 Flight Control System

The planned use of the Flight Control System during Static Test SF-002 included gimbaling the engines from the null to the start positions prior to engine ignition, gimbaling from the start to the run positions after thrust buildup, gimbaling from the run to the shutdown positions prior to cutoff, and gimbaling back to the null position after the firing. The Flight Control System performed satisfactorily during the test, with the ATVC drivers properly commanding the engine actuators to gimbal the engines to the required positions in response to input commands from SATS via the FC-MDM.

Engine sideloads during engine ignition and shutdown cause some engine movement, as indicated by the ATVC actuator position measurements. The most significant sideload measurement, which appeared on Engine 2 in the pitch axis, indicated a transient movement of the engine bell of approximately one degree peak-to-peak. Although a large pressure surge (approx. 1600 psi) was observed in the primary hydraulic system at the time of the sideloads, no significant hydraulic surge was indicated by the actuator secondary hydraulic pressure measurement. There was no indication, therefore, that the secondary pressures would approach the levels where an actuator error indication would be generated by the failure detection circuit.

4.2.4 Data Processing System (DPS)

The MPTA DPS system, which consists of the FC-MDM, OI-MDM, the three EIU's, and the data bus system, operated satisfactorily during Static Firing Test SF-002.

Section 4.3 Hydraulic System Analysis

During the second MPTA static firing, the primary hydraulic system test objectives were:

- (a) Verify the hydraulic system has the capability to meet the prelaunch warmant flow requirements (pressure, temperature and flow) of the Orbiter/SSME Interface Control Document (ICD) 13M15000.
- (b) Obtain prelaunch warmant flow data to verify the hydraulic system math model and to support hydraulic system thermal analysis.
- (c) Evaluate hydraulic system pressure transients when the engines are gimballed and also during engine start, engine run and engine shutdown.

4.3.1 Hydraulic System Performance

This test was conducted with purge gas flowrates through the aft fuselage compartment approximately the same as the flow rates used during static firing MPT-S1-001. However, all hydraulic system temperatures were generally warmer than those experienced on previous static firings (Refer to Figure 4.3.1-1) due to the combination of (1) increased fluid temperature at the facility/GSE interface (as planned) and (2) a hot day. This condition also caused the hydraulic system delta temperatures to be less than those encountered on previous static firings. Another important data point was obtained for warmant flow evaluation.

The hydraulic flowrate data during the simulated warmant flow mode is not useful because the flowrates were below the sensitive range of the 0 to 80 gpm GSE flow transducers. These transducers are in the return lines of the S70-0756 unit. Useful flow data will be obtained when additional low range flow transducers are added to the Orbiter/SSME interface for static firing #5. The expected warmant flowrate range will be 0.12 to 0.38 gpm as specified in ICD 13M15000.

The significant hydraulic temperatures during warmant flow are shown in Figures 4.3.1-1 through 4.3.1-8. ICD 13M15000 requires that the Orbiter/SSME interface temperature be maintained at 60°F or above from propellant loading to simulated APU start.



This requirement was met because the temperature range was 92°F to 97°F for all three engines. Figure 4.3.1-3 presents data for engine 3. This data is typical for the other two engines.

Hydraulic fluid outlet temperatures for the main oxidizer valves (MOV) and main fuel valves (MFV) are a redline with a lower limit of -20°F during warmant flow. These temperatures must also be 35°F minimum from T_O-3 minutes until engine start. All valve temperatures were well within these limits. Figures 4.3.1-4 and 4.3.1-5 present temperature profiles for engine 2 MOV and MFV, respectively. MOV temperatures for the other two engines were 2°F to 5°F warmer than engine 2. However, the MFV temperatures for the other two engines were approximately 18°F warmer than the temperature at engine 2. The MFV outlet temperature at engine 2 was also colder during static firings MPT-S1-001 and MPT-S1-002 (Refer to Section 4.3 of SD78-SH-0077) and is still under investigation. Figures 4.3.1-4 and 4.3.1-5 also show the expected rapid heatup rate when hydraulic pressure is increased to 3000 psi.

The significant hydraulic system pressures during this test are shown in Figures 4.3.1-9 through 4.3.1-14. ICD 13M15000 requires that a 200 psid minimum differential pressure at a specified flow be maintained across each engine during warmant flow. As previously stated, flow cannot be verified at this time. The differential pressure across each engine was maintained between 220 psid and 230 psid. Therefore, the minimum requirement was met. Figures 4.3.1-11 and 4.3.1-12 present data for engine 3. This data is typical for the other two engines.

Hydraulic pressure transients were nominal when (1) gimbaling to the start, run and shutdown positions and (2) slewing the engine propellant valves for engine start and engine shutdown. The pressures ranged from 50 psi to 250 psi on the supply side and 20 psi to 110 psi on the return side. Some greater pressure spikes/dropouts were experienced as discussed below in Section 4.3.1.1.

4.3.1.1 Engine Sideloads

During the engine start and shutdown transients, it was observed that engine 2 thrust chamber movement was considerable when compared to the relative inactivity of the other two engines. This movement has been attributed to engine sideloads experienced during thrust buildup and thrust decay. It is

noted that the sideloads are higher than predicted but are well within actuator load capability.

Figures 4.3.1.1-1 and 4.3.1.1-2 present engine 2 pitch and yaw actuator positions while Figures 4.3.1.1-3 and 4.3.1.1-4 present engine 2 pitch and yaw actuator cylinder differential pressures. As can be seen, the pitch actuator experienced a maximum movement of ± 0.5 degrees and the corresponding maximum cylinder ΔP was 1500 psid (vs. a predicted 650 psid). Engine 2 yaw actuator parameters are slightly less. Also, the parameters for the other two engines were negligible. Figure 4.3.1.1-5 presents hydraulic supply pressure at engine 2 Orbiter/SSME interface for this same time period. The pressure spiked to 3400 psi and dropped to 2540 psi because the sideload activity is the same as an actuator step input. These pressure excursions did not threaten the engine propellant valves because shutdown had already been achieved. Other hydraulic system pressure transients were considerably less than those shown in Figure 4.3.1.1-5. The fact that engine 2 moved more than the other engines is currently under investigation.

4.3.1.2 Conclusions

Performance of the facility, GSE, and test article hydraulic systems was satisfactory.

With the exception of warmant flow verification, all Orbiter/SSME ICD warmant flow requirements were met.

Hydraulic pressure transients during gimbaling, engine start, engine run and engine shutdown were nominal.

Thrust chamber movement for engine 2 was considerable when compared to the relative inactivity of the other two engines.

This incident is under investigation.

05CT0001H
HYDRA PWR INLET FLUID TEMP
DEG F

TEST NO MPT5F2
RECORDED 114
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

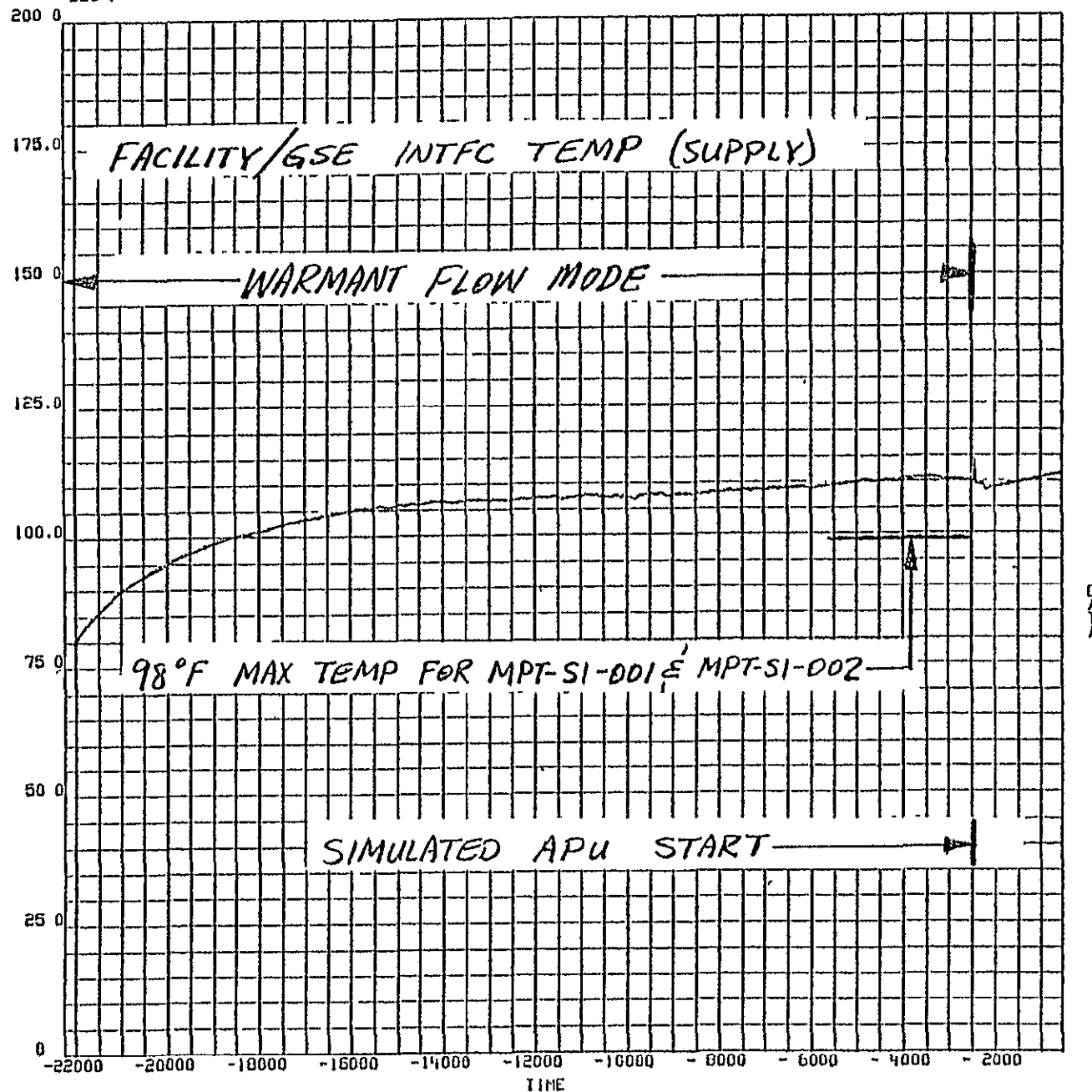


FIGURE 4.3.1-1

A5079931H
HPS 3 SPLY LN NON-P/P INTFC TEMP
DEG F

TEST NO MPTSF2
RECORDER HF2
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

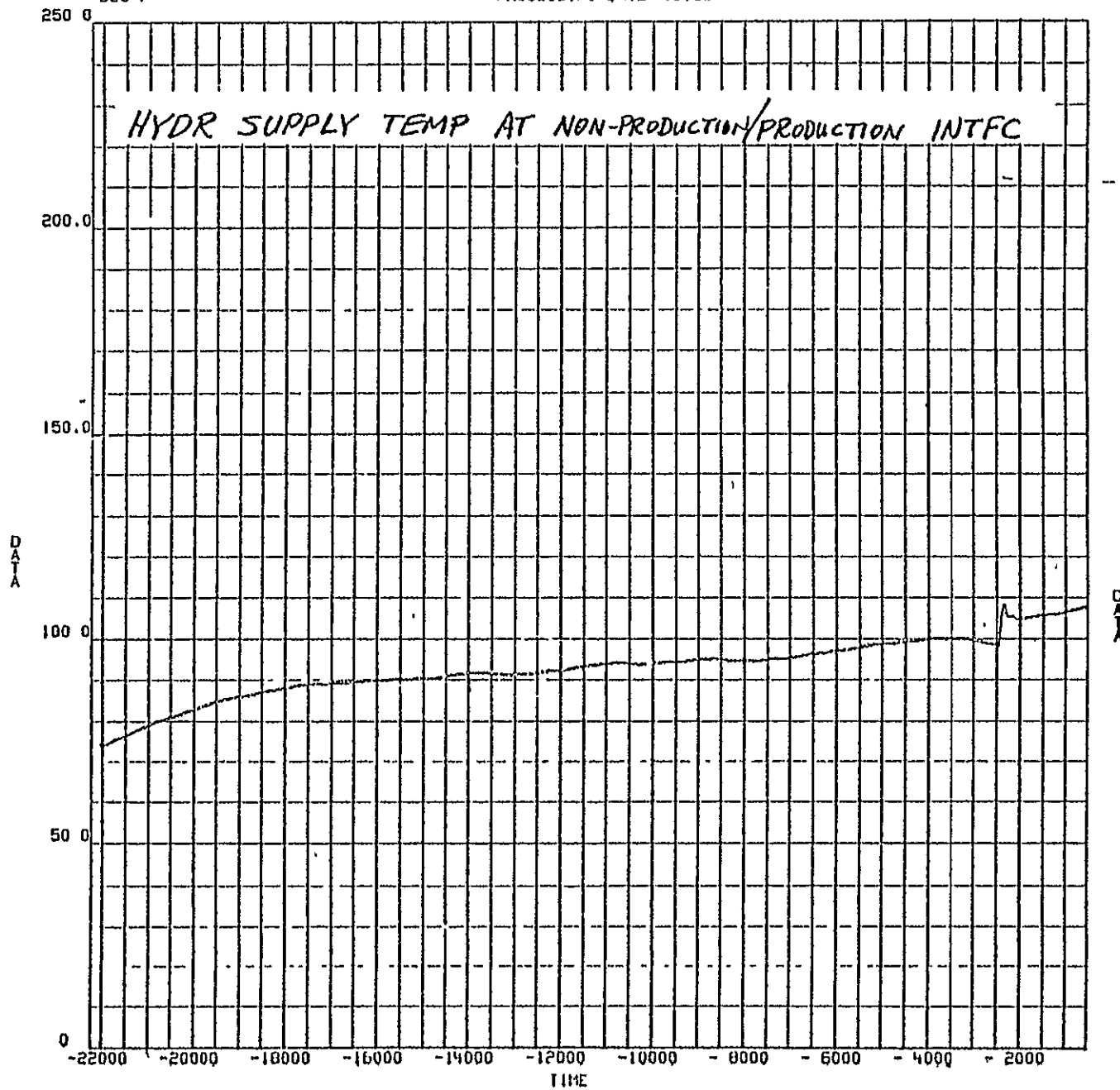


FIGURE 4.3.1-2

V50T1330A
HYDR SYS MC-3 INTFC PRESS LN TEMP
DEG F

TEST NO NPTSF2
RECORDER IT
PROCESSING DATE 78141

DATE TIME
70 139 14 10 56 10

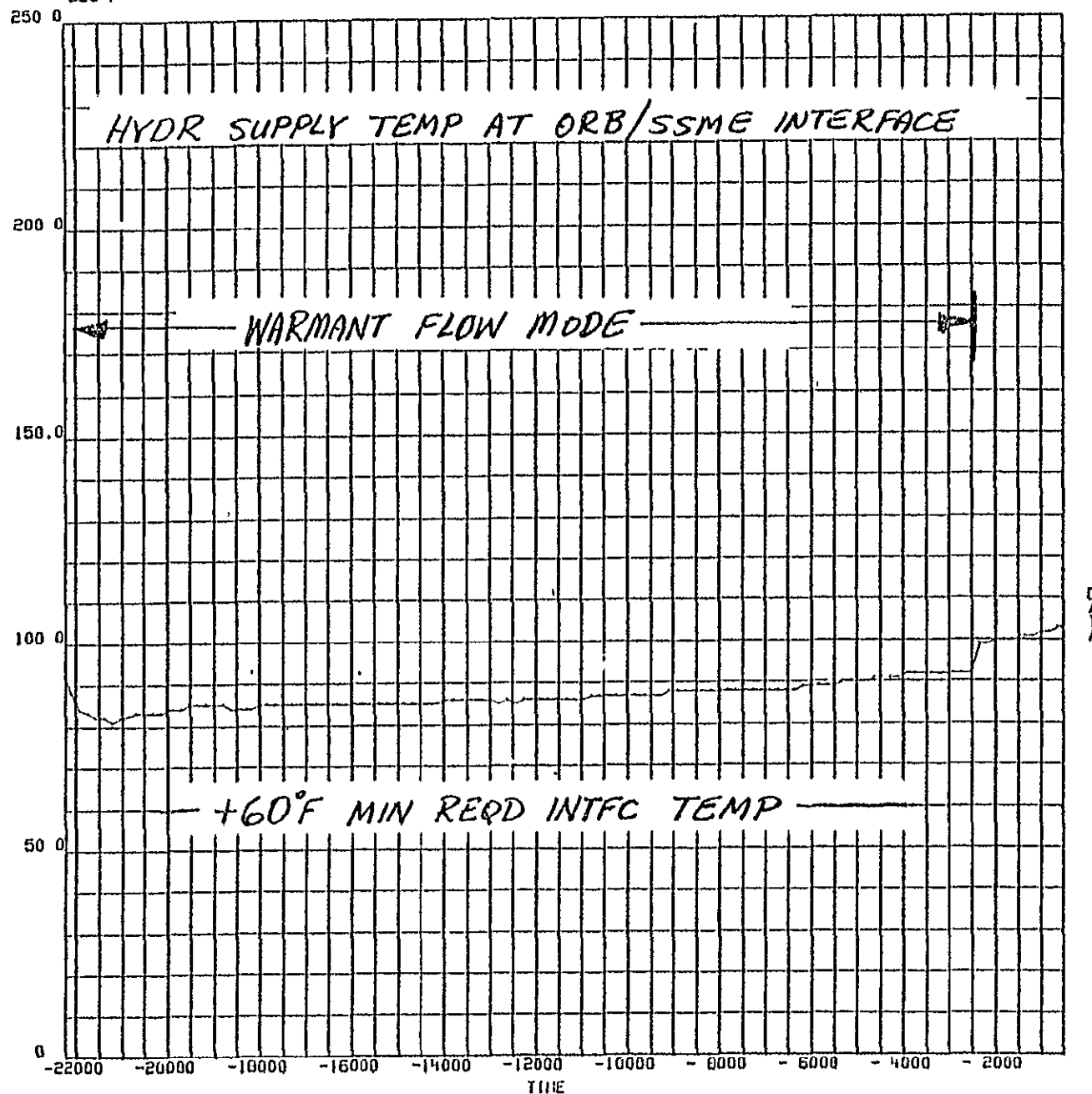


FIGURE 4.3.1-3

A49T2157H
ME-2 MOV ACTR HYDR OUT TEMP NO 1
DEG F

TEST NO MPT5F2
RECORDER HF2
PROCESSING DATE 70139

BASE TIME
70 139 14 10 56 10

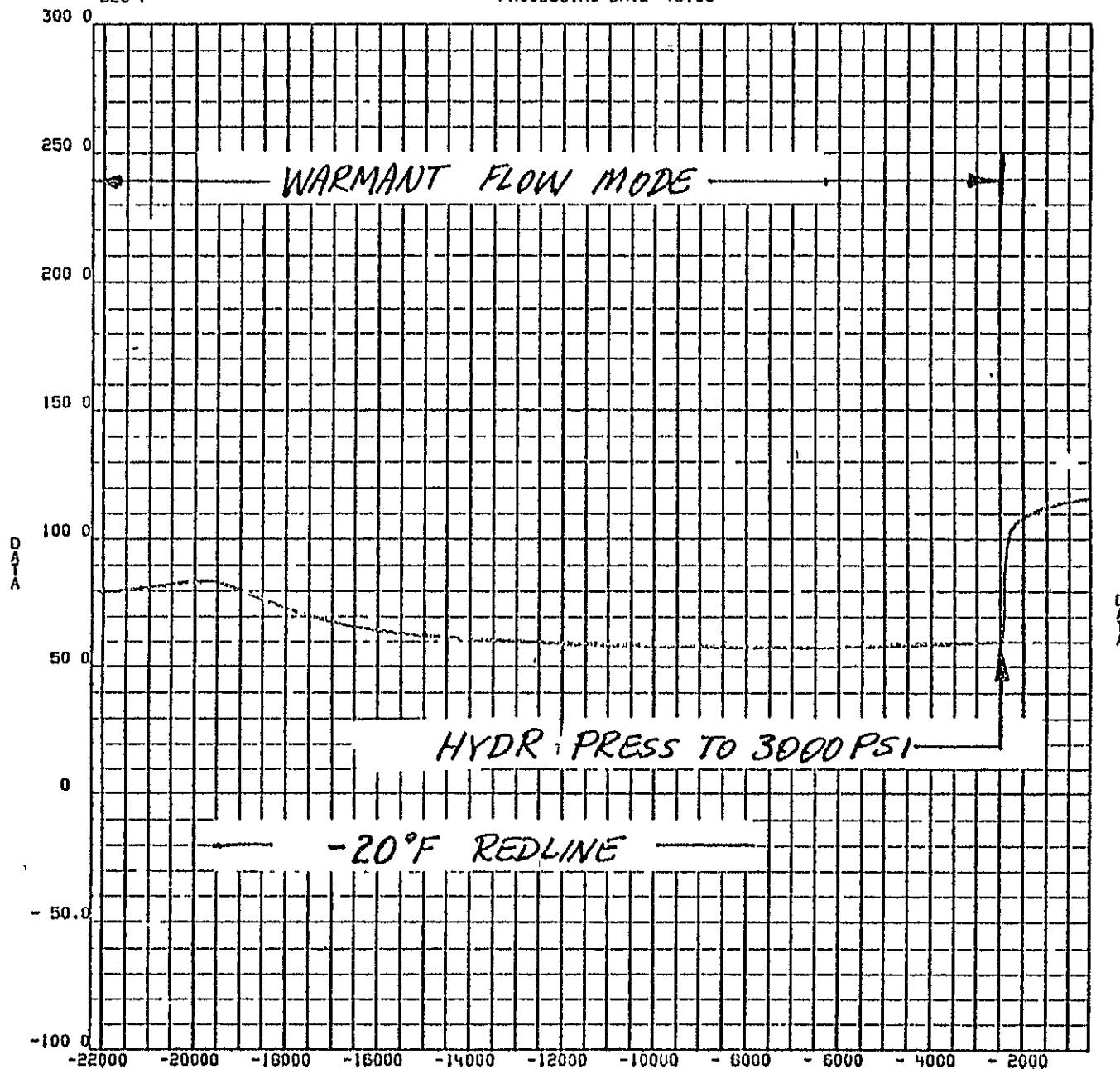


FIGURE 4.3.1-4

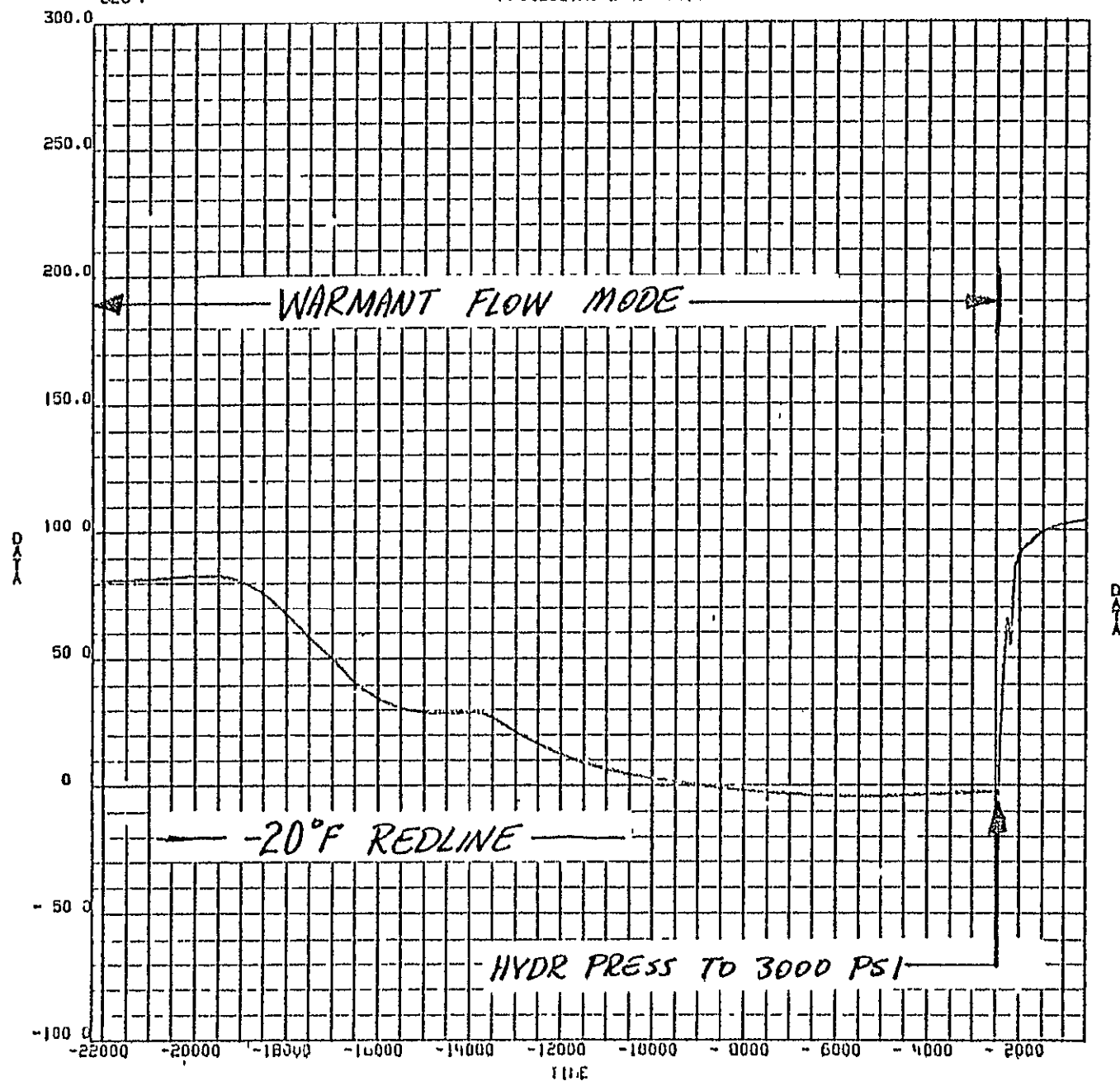
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A491215GH
ME-2 MFV ACTR HYDR OUT TEMP NO 2 (DEG F

TEST NO MP15F2
RECORNER hf2
PROCESSING DATE 79139

BASE TIME
78 139 14 10 55 10



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FIGURE 4.3.1-5

V58T1331A
HYDR SYS ME-3 INTFC R LINE TEMP
DEG F

TEST NO MPT9F2
RECORDER IT
PROCESSING DATE 78141

BASE TIME
78 139 14 10 55 10

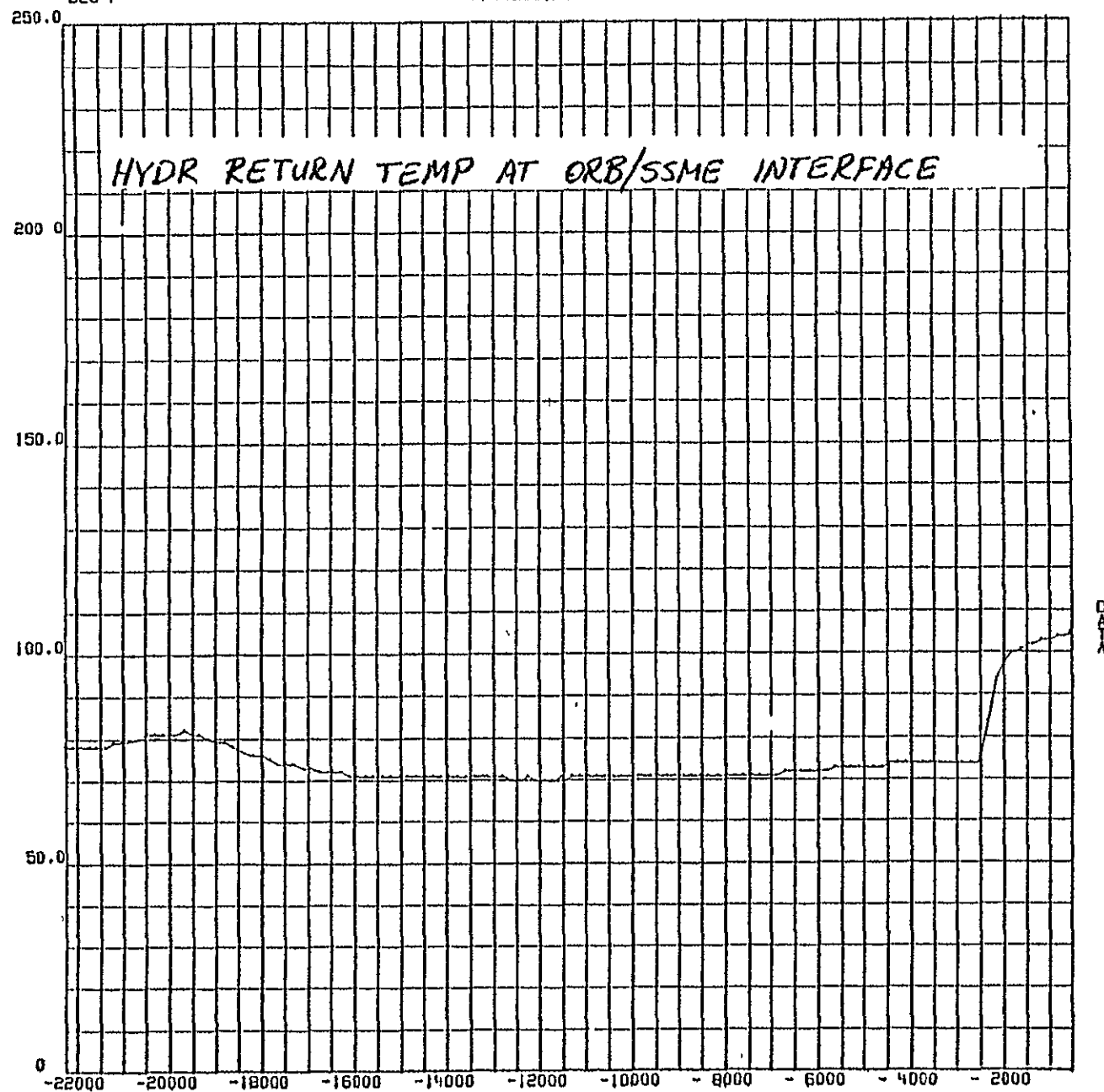


FIGURE TIME 4.3.1-6

A5819932H
HPS 3 RTN LN NON-P/P INTFC TEMP
DEG F

TEST NO 11PTSF2
RECORDER HF2
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

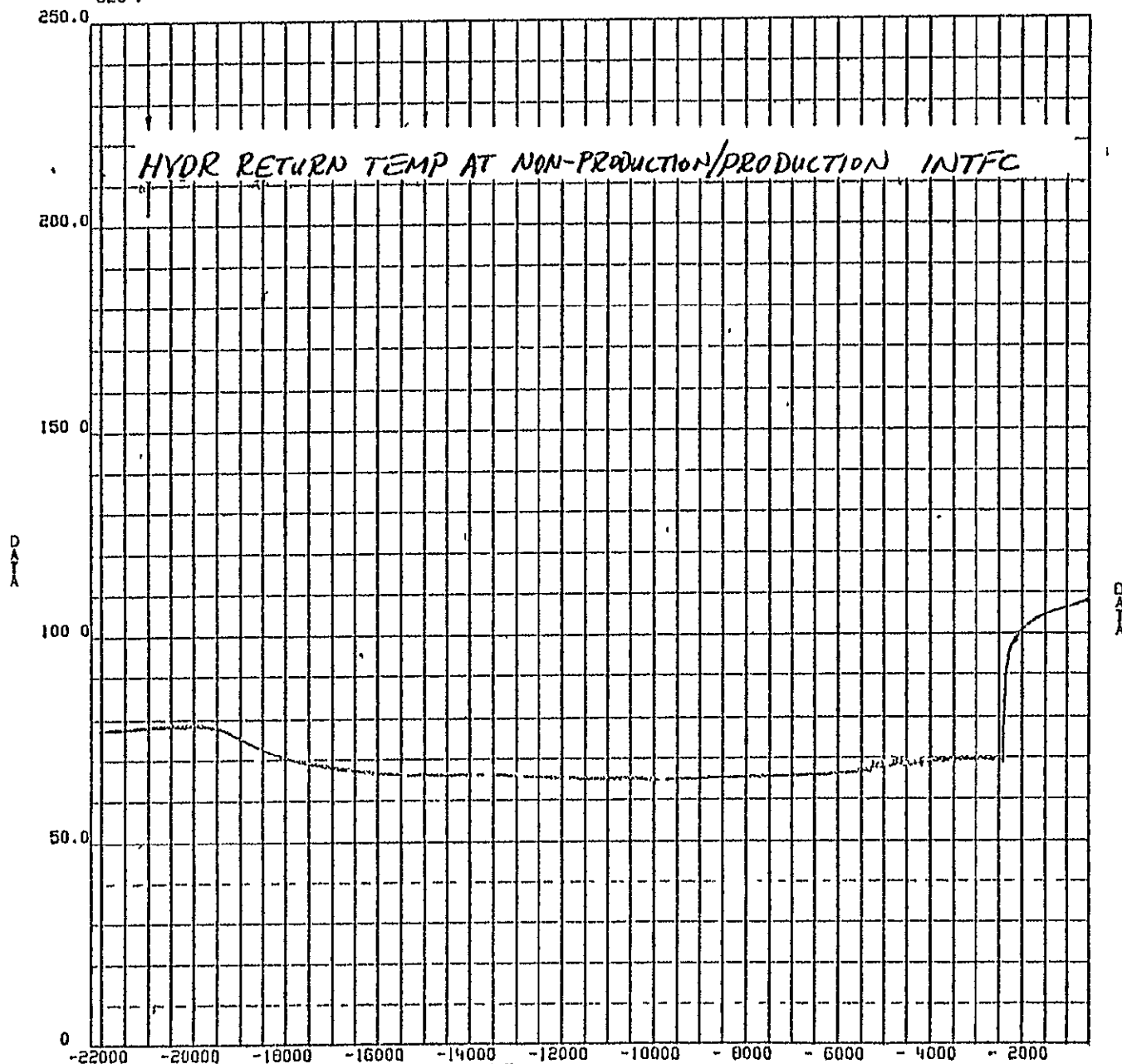


FIGURE 4.3.1-7

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G58T9804H
HYDR PWR RETURN FLUID TEMP
DEG F

TEST NO IPTSF2
RECORDER IF4
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

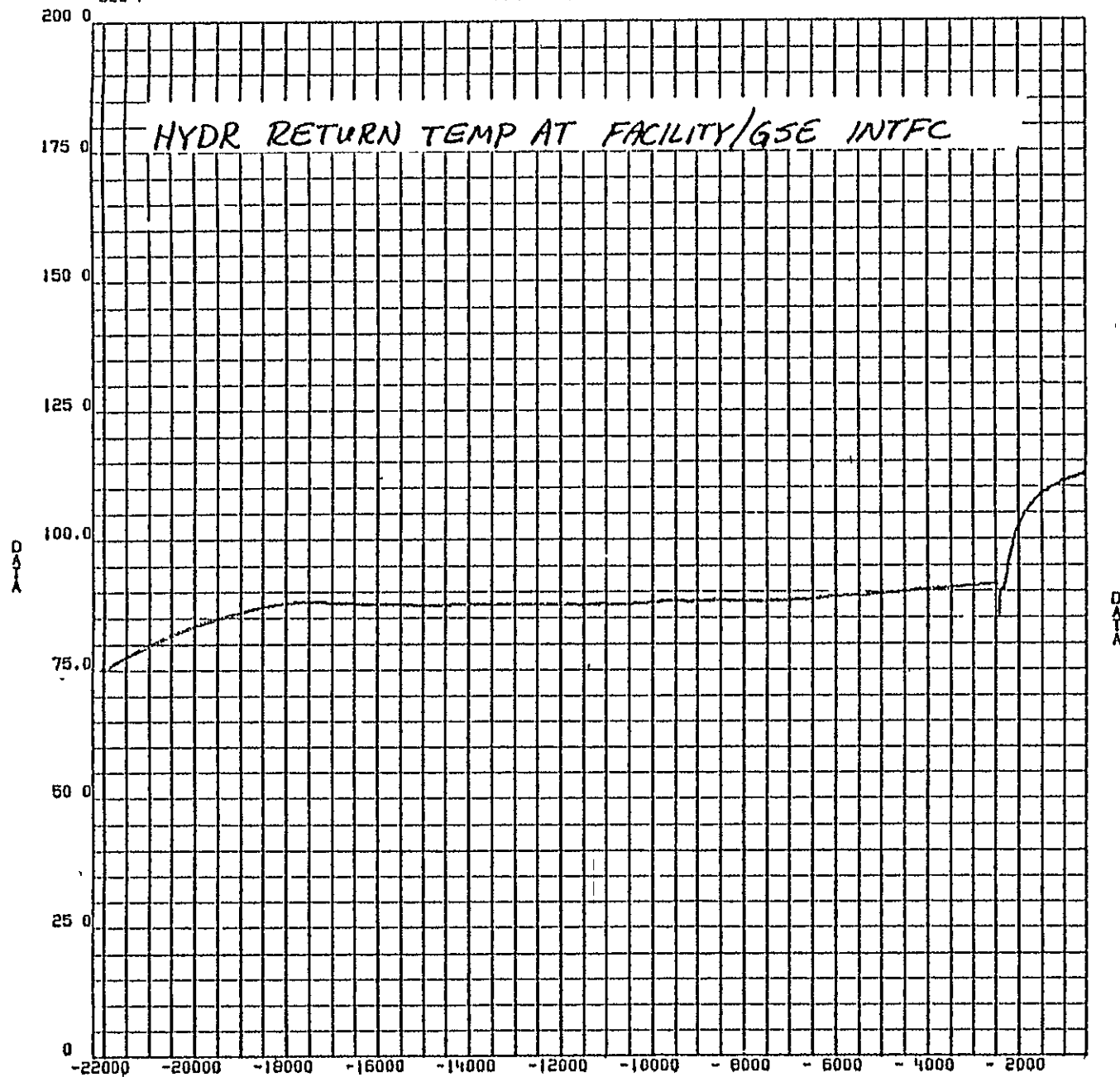


FIGURE 4.3.1-8

SD78-SH-0125

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GM: P9021H
HYDR PWR SUPPLY FLUID PRESS
PSIG

TEST NO MPTSF2
RECORDER HI 3
PROCESSING DATE 70139

BASE TIME
70 139 14 10 56 10

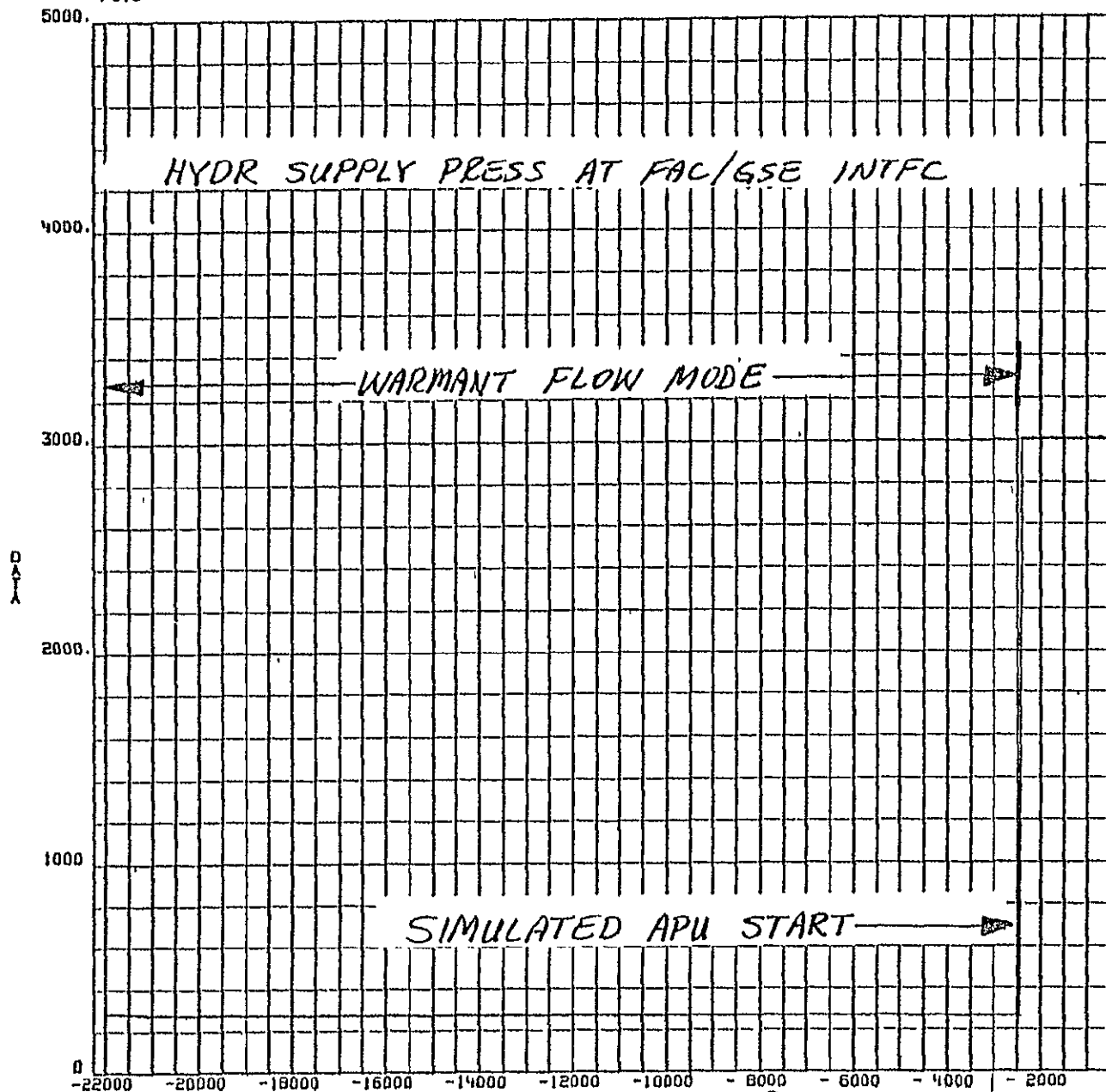


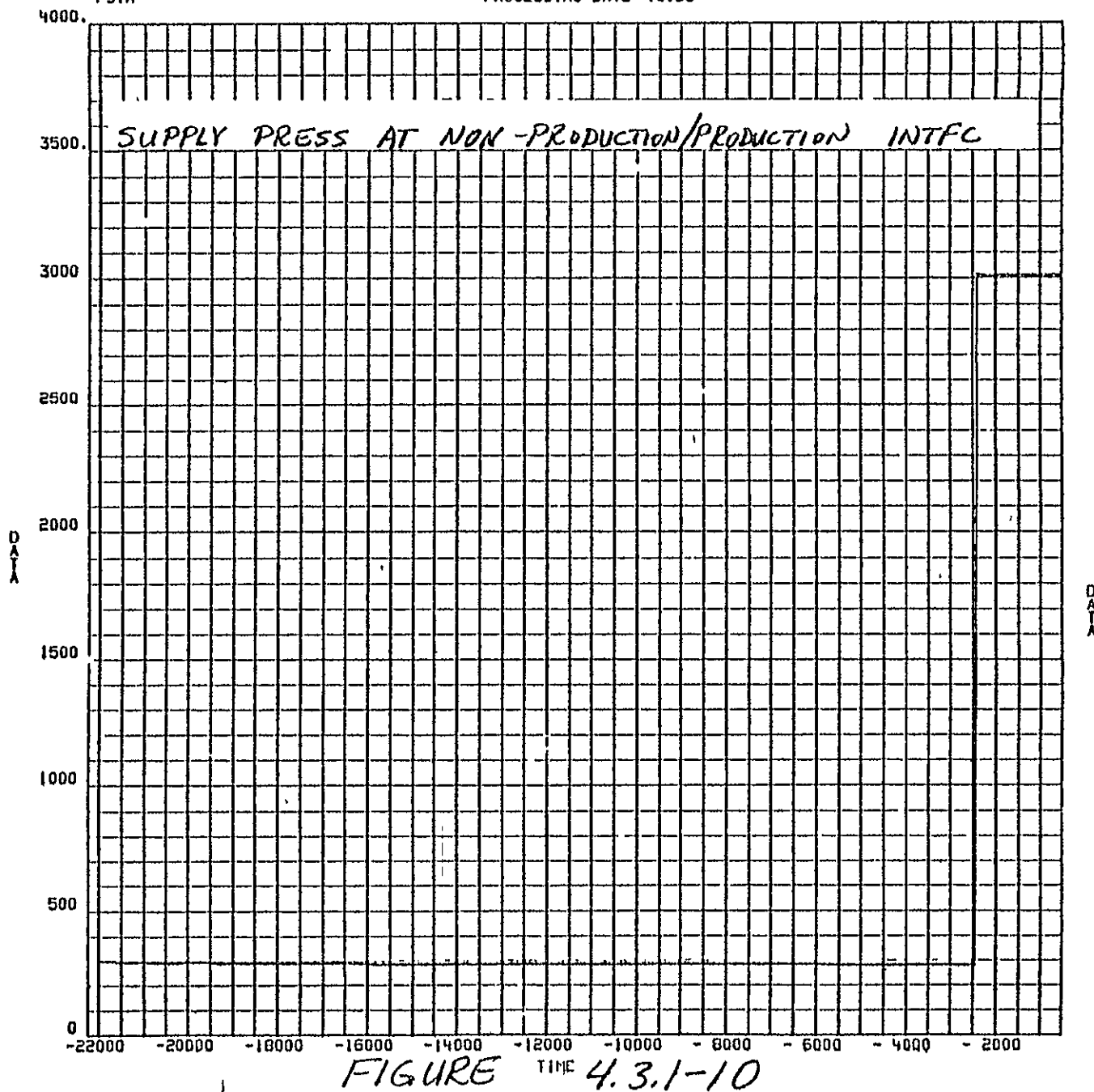
FIGURE 4.3.1-9

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A50P9935H
HPS 3 SUPPLY LN NON-P/P INTFC PRES
PSIA

TEST NO MPTSF2
RECORDER HF3
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10



A50P1340H
HYDR SYS ME-3 INTFC P LINE PRESS
PSJA

TEST NO MP1SF2
RECORDER HF3
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

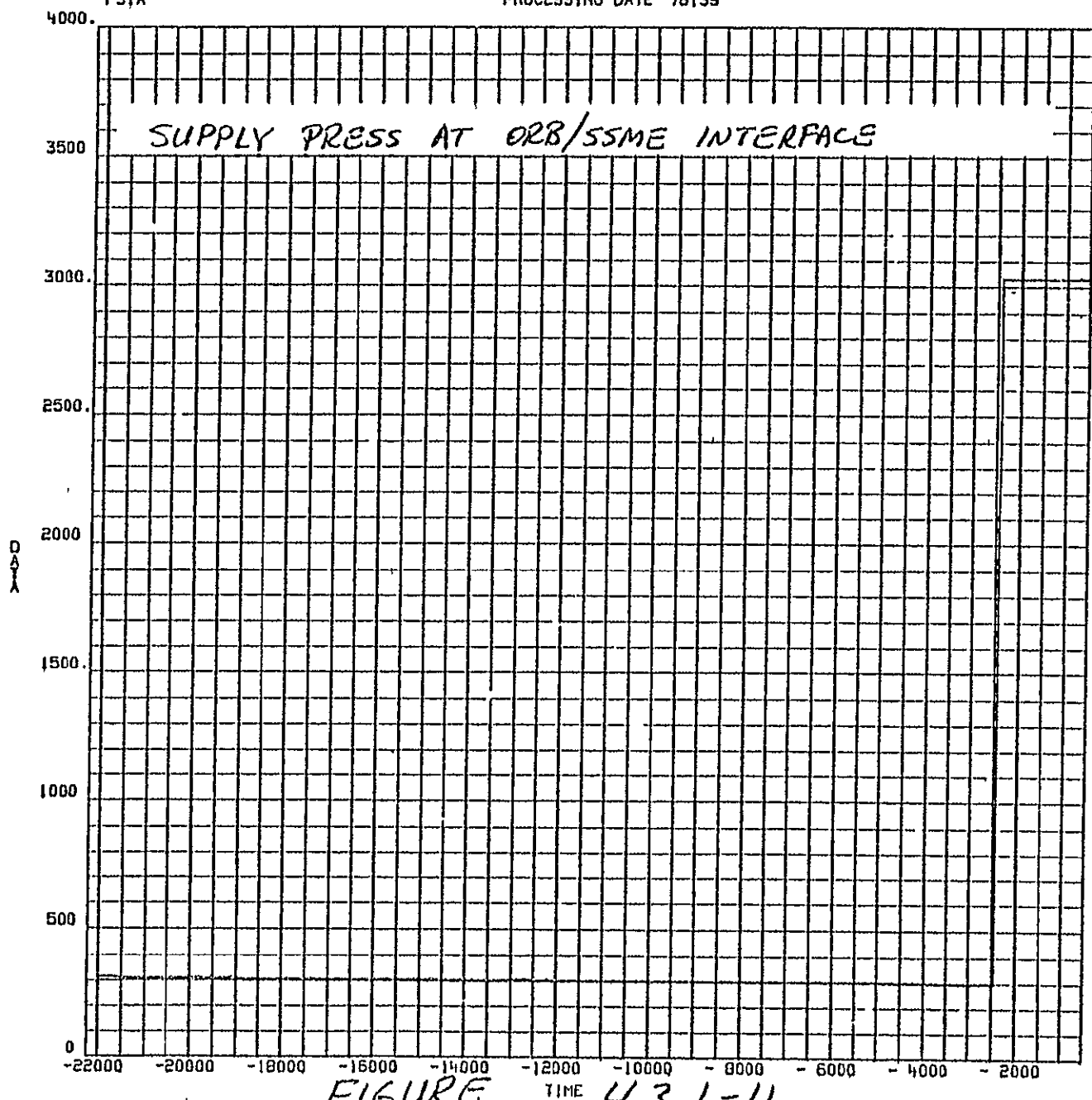


FIGURE 4.3.1-11

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A58P1341H
HYDR SYS ME-3 INTFC R LINE PRESS
PSIA

TEST NO MPTSF2
RECORDER HF3
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

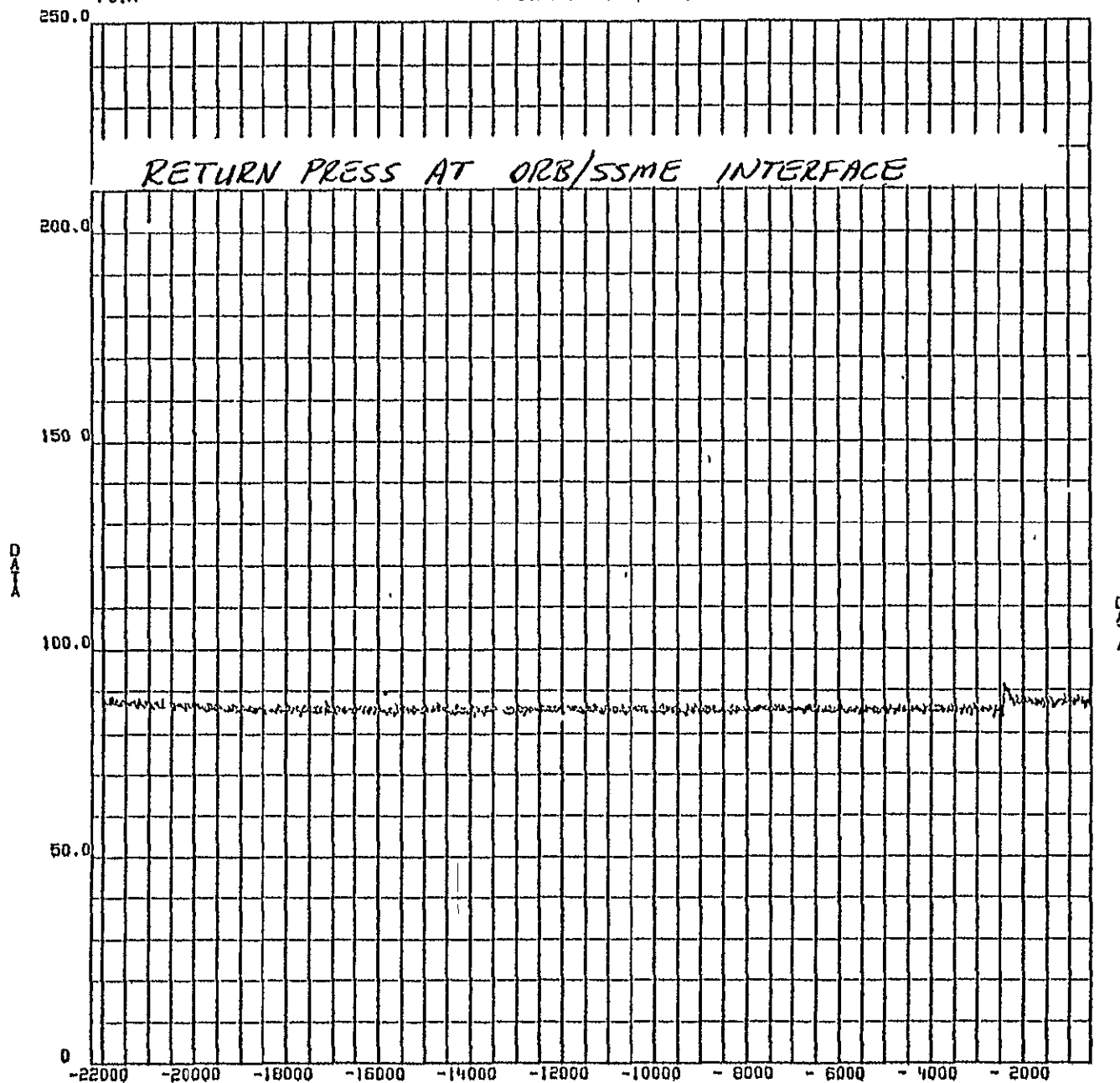
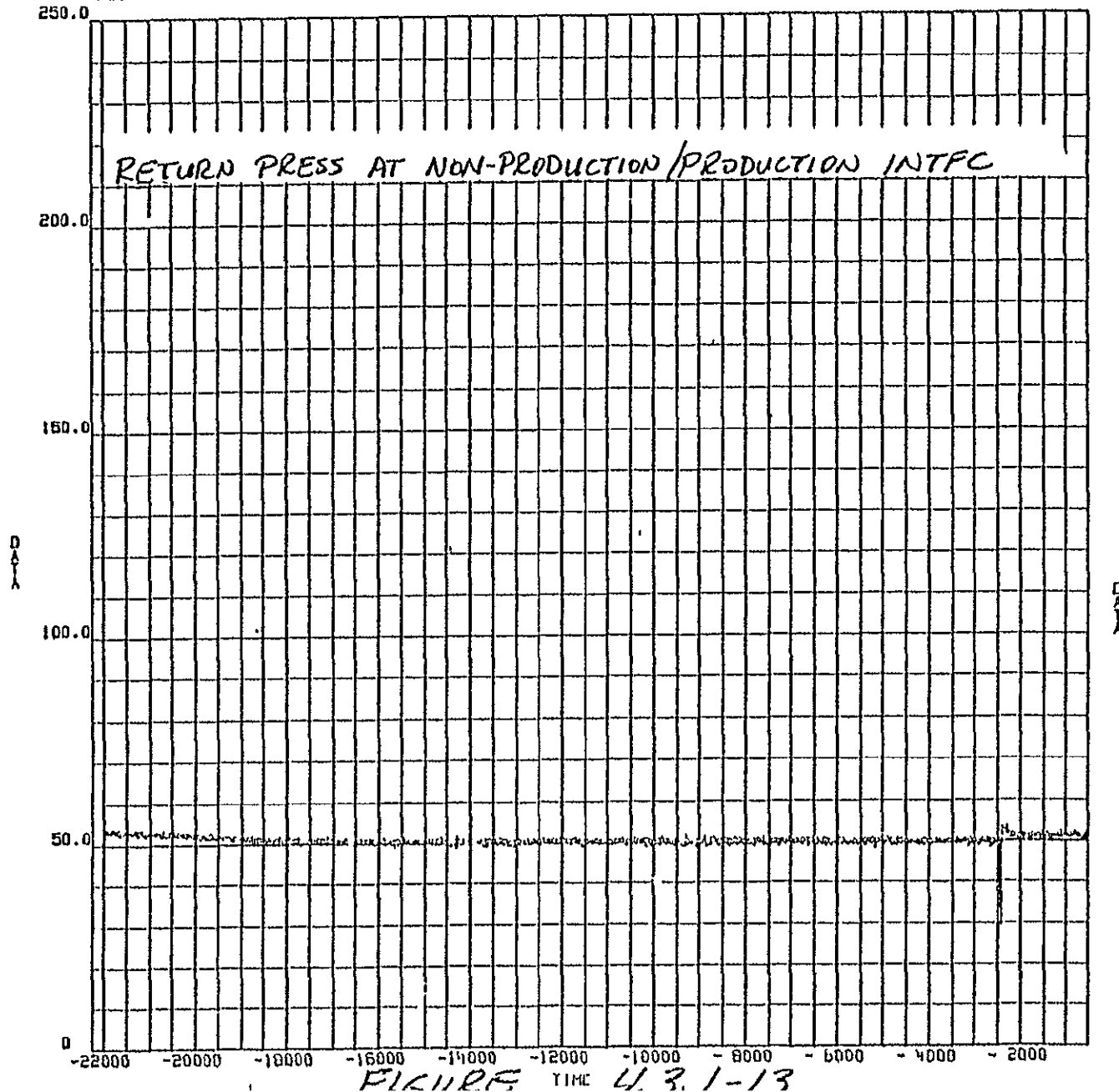


FIGURE 4.3.1-12

A50P9936H
HPS 3 RTN LN NON-P/P INTFC PRESS
PSIG

TEST NO MPISF2
RECORDER HF3
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10



050P9824H
HYDR PHR RETURN FLUID PRESS
PSIG

TEST NO MPTSF2
RECORDER HF3
PROCESSING DATE 78139

BASE TIME
78 139 14 10 56 10

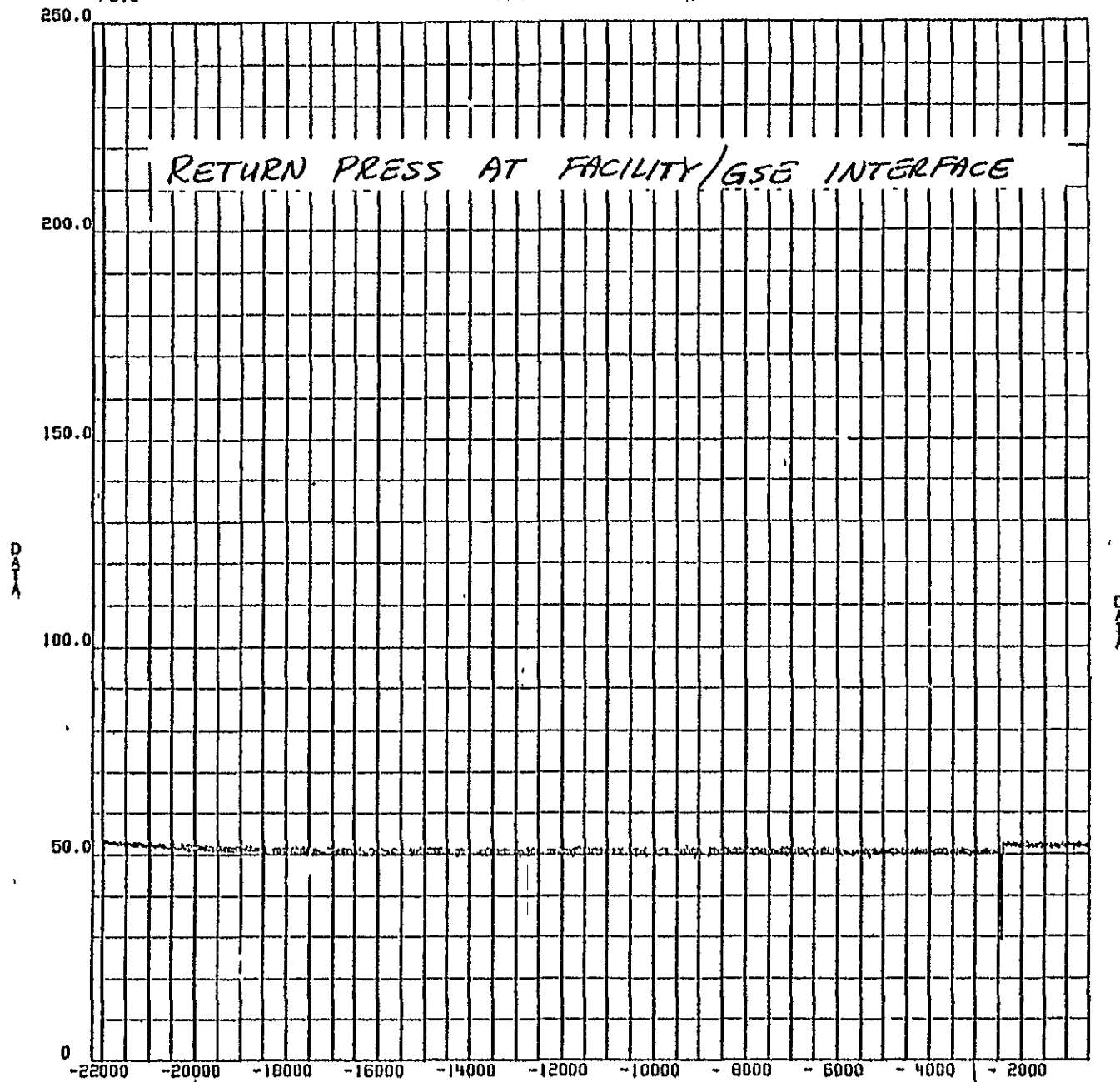


FIGURE 4.3.1-14

V50H1200K

TEST NO

MPISF2

BASE TIME

10

ENG 2 PITCH ACTR POSITION

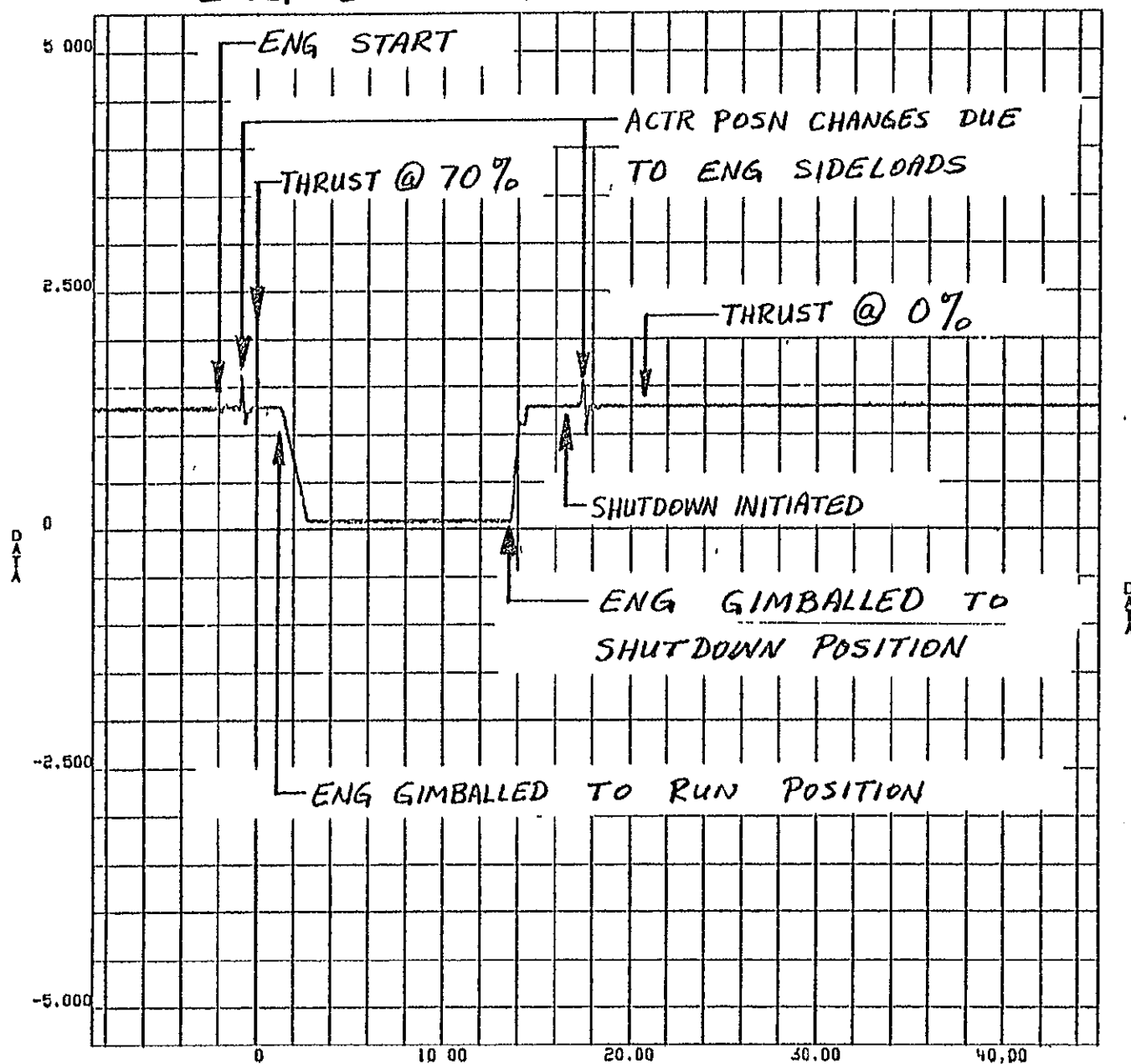


FIGURE 4.3.1.1-1

V58H1250K
MPS ENG 2 Y ACTR POSN
INCHES

TEST NO MP1SF2
RECORDER ES
PROCESSING DATE 78140

BASE TIME
78 139 14 10 56 10

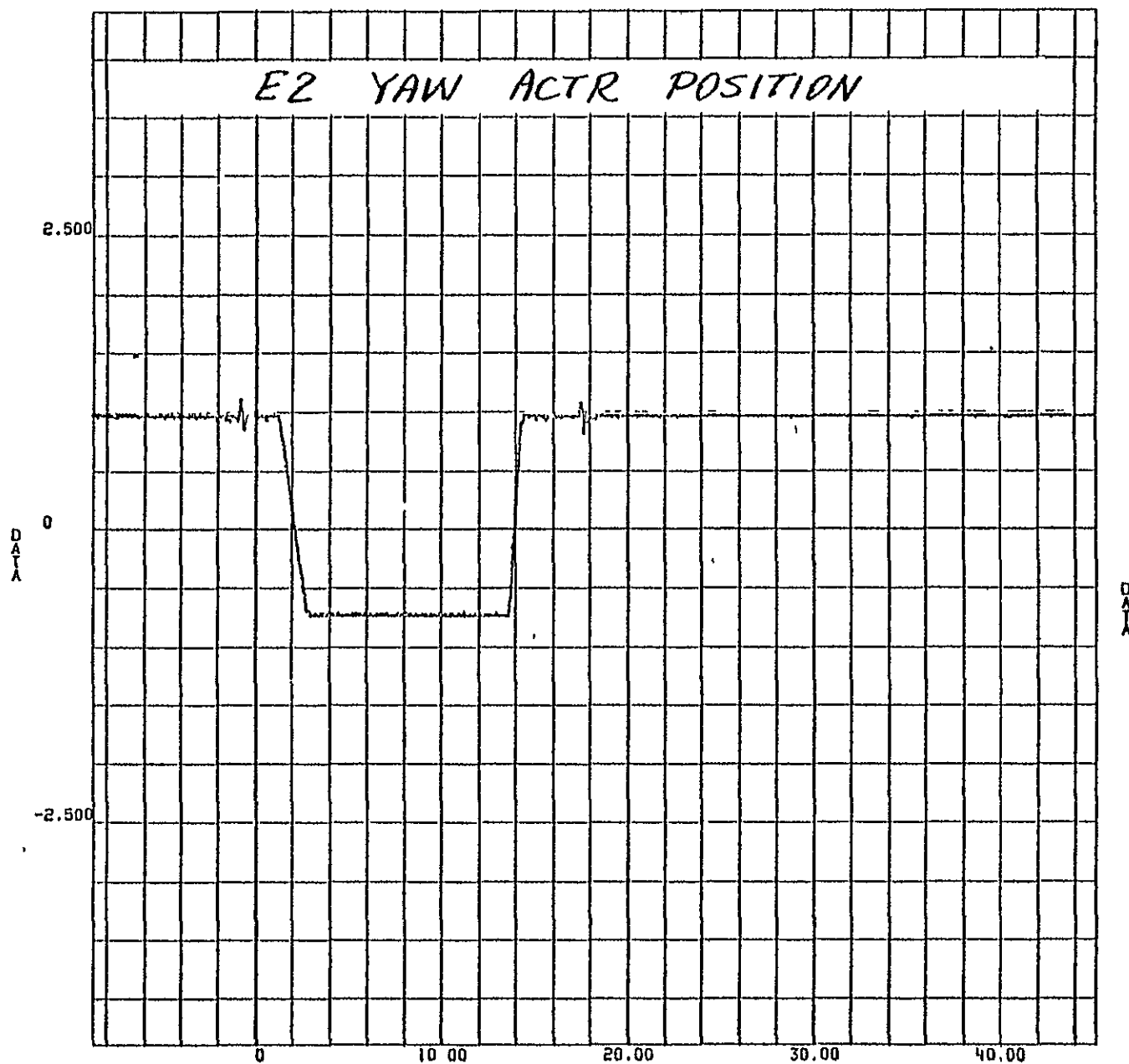


FIGURE TIME 4.3.1.1-2

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V58P9002A
ME2 PITCH TVC HYDR ACTR DIFF PRESS
PSIO

TEST NO MPTSF2
RECORDER JT
PROCESSING DATE 78140

BASE TIME
70 139 14 10 56 10

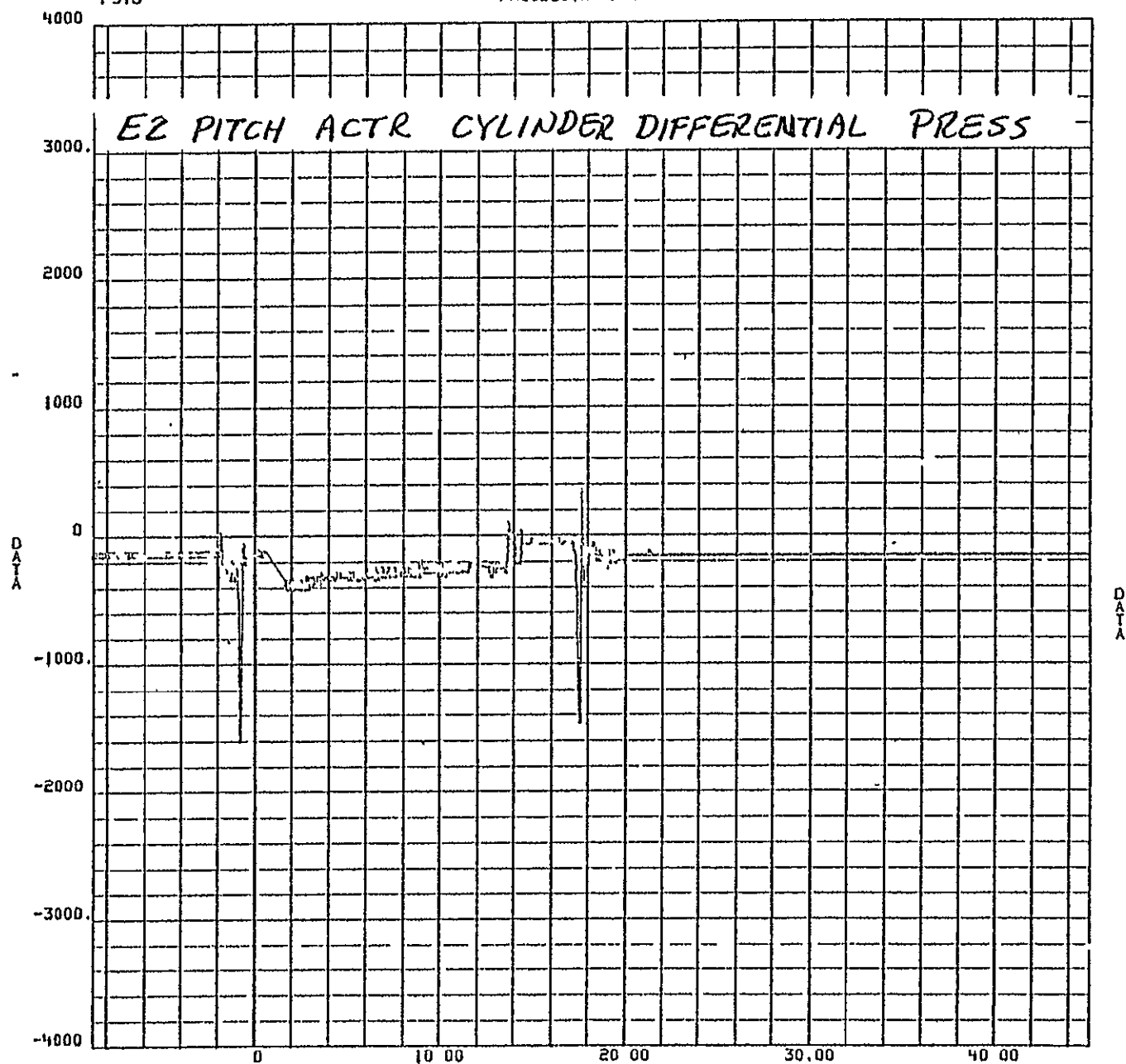


FIGURE 4.3.1.1-3

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V50P9086A
ME2 YAW TVC HYDR ACTR DIFF PRESS
PSIO

TEST NO MPTSF2
RECORDER 31
PROCESSING DATE 78140

BASE TIME
78 139 14 10 56 10

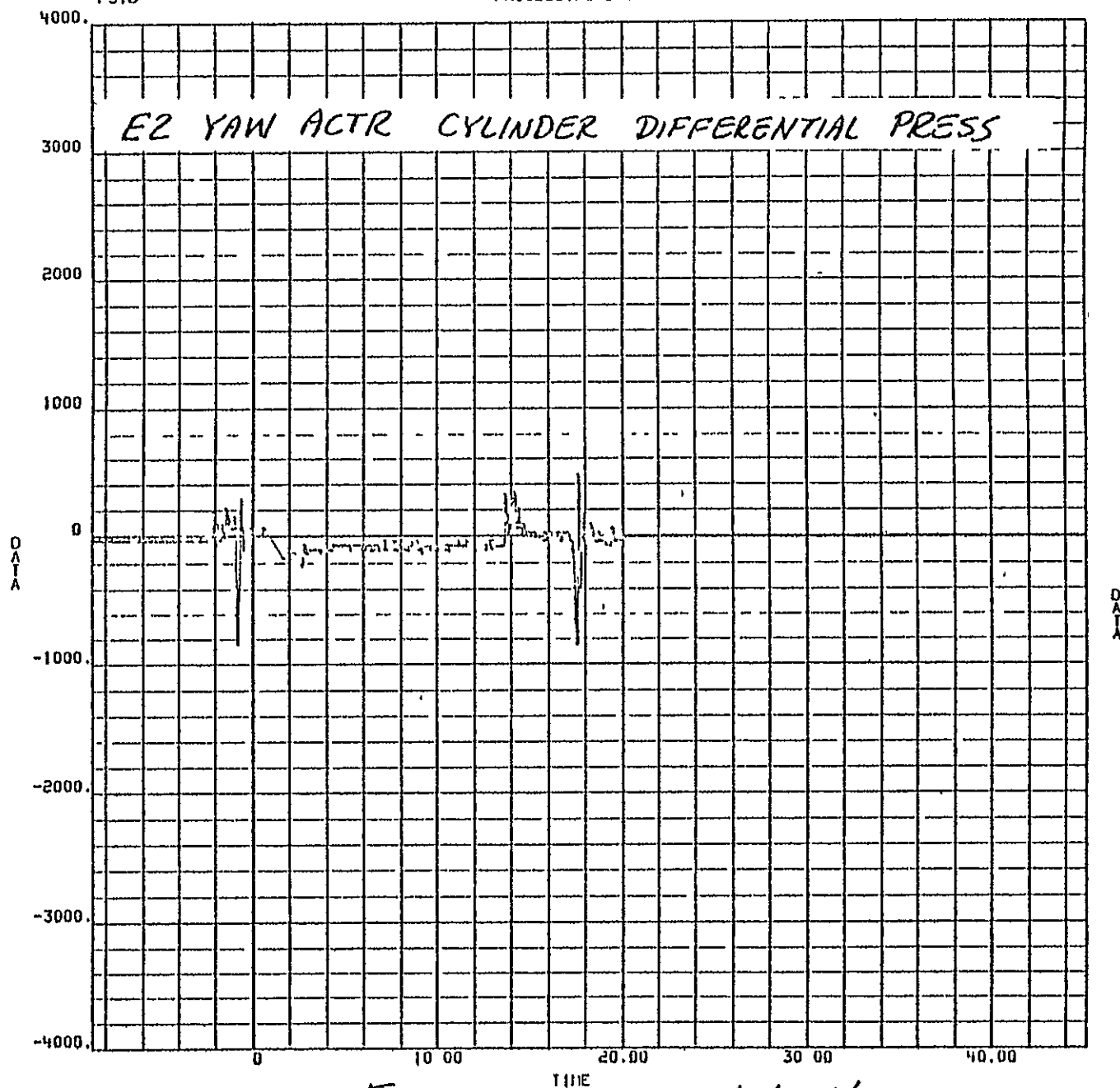


FIGURE 4.3.1.1-4

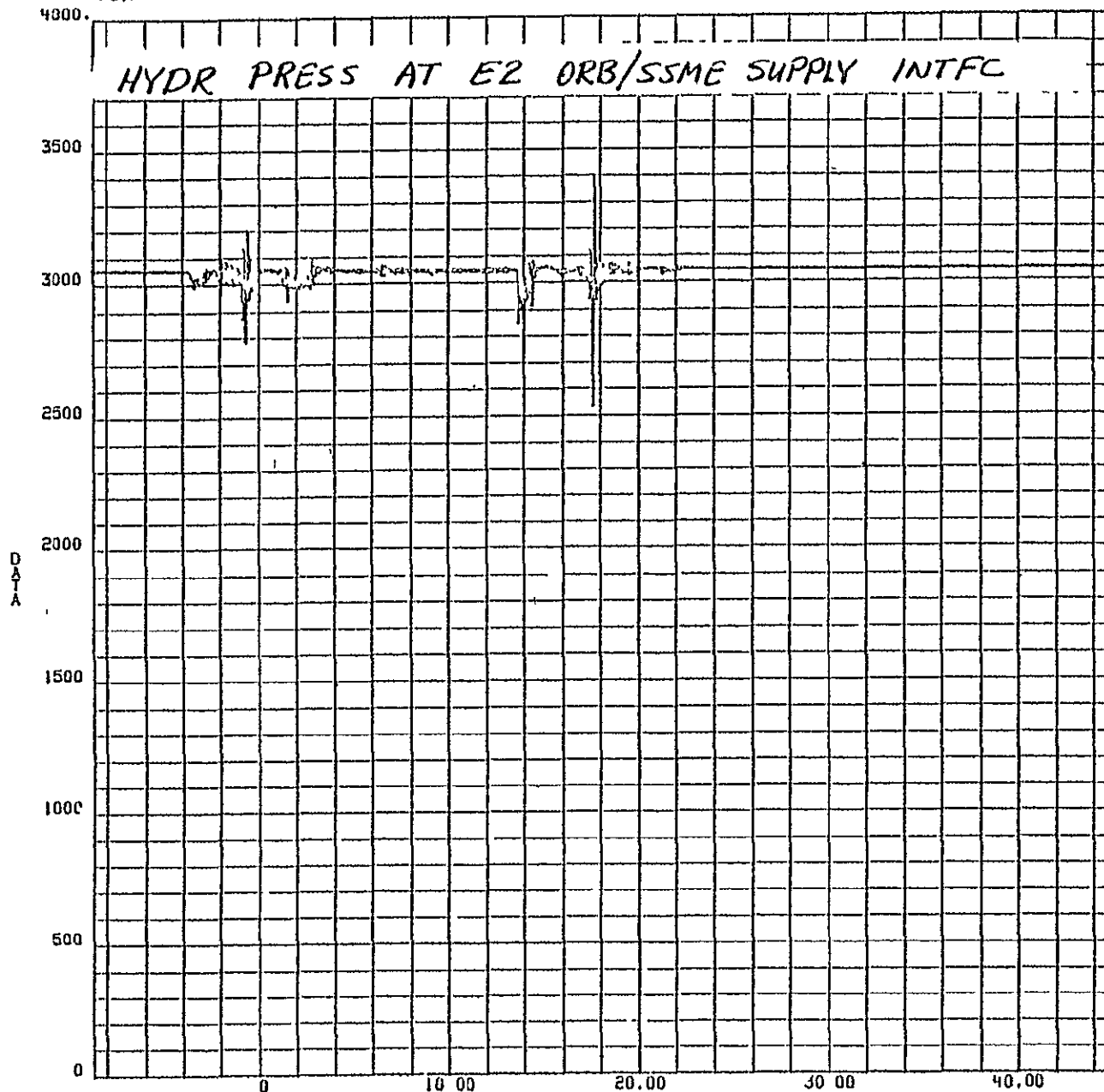
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SD78-SH-0125

A58P1240H
HYDR SYS ME-2 INTFC P LINE PRESS
PSJA

TEST NO MPISF2
RECORDER HF3
PROCESSING DATE 70140

BASE TIME
78 139 14 10 56 10



DATA

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FIGURE 4.3.1.1-5

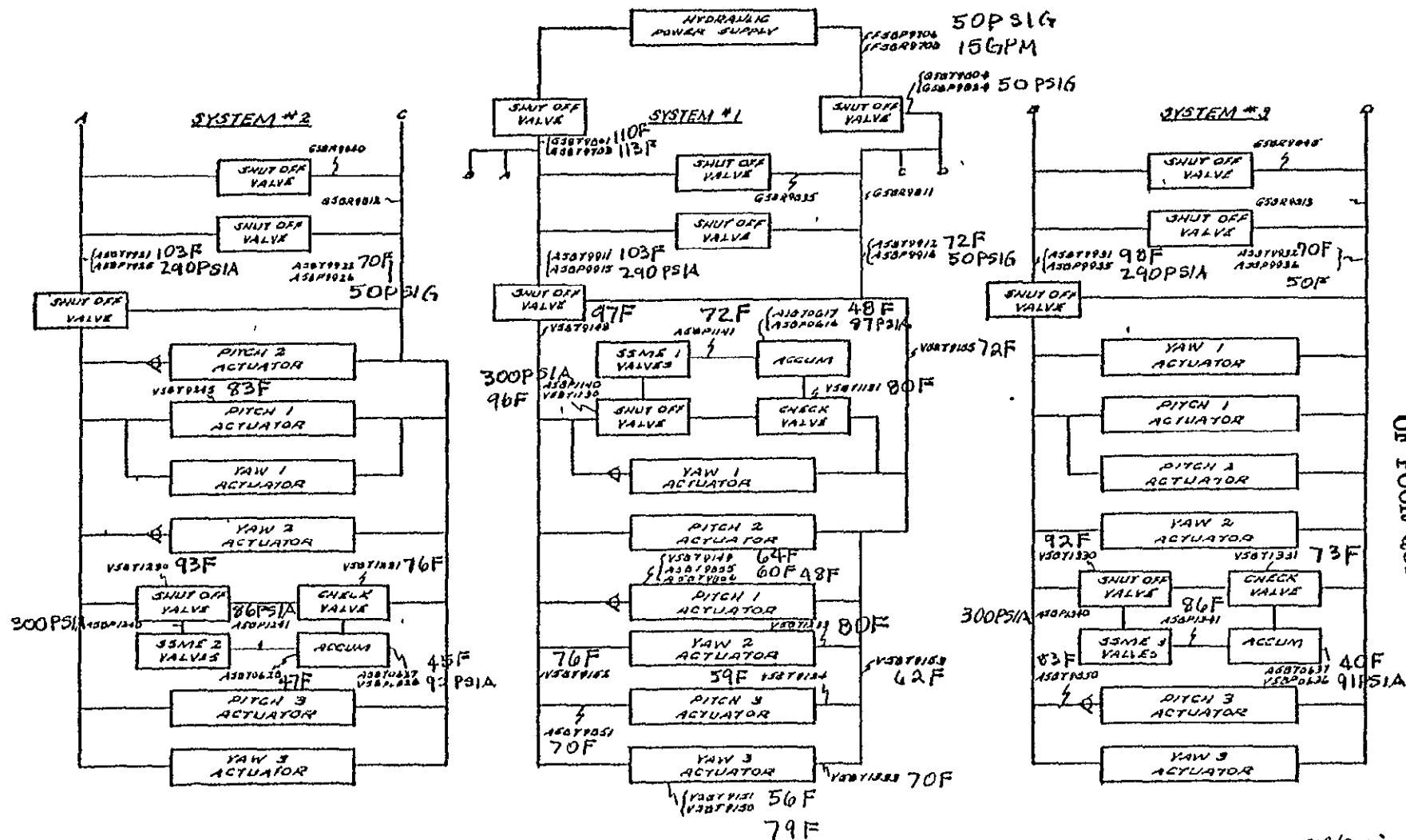


4.3.2 Hydraulics - Thermodynamics

The recorded available data from SF-2 5/19/78 has been reviewed. The data show that no temperature problems occurred on the Orbiter hydraulics systems during the low and high pressure flow periods of the tests. System temperatures were from 10 to 15°F higher than temperatures from the previous test due to a higher fluid supply temperature from the Greer Unit and slightly warmer environments. Flows have not yet been measured, so no SSME HAS heat balances have been calculated to date. Because of slightly higher system temperatures, the cooldown rate of the standby line increased to ~ 3.3 °F/min. from ~ 2.7 °F/min for the previous tests. Figures 4.3.2.1 through 4.3.2.4 present the current test data. Figure 4.3.2.1 shows data at 5 hours after the start of cryo fill at low (circulation pump) pressures. Figure 4.3.2.2 shows data after going to high (main pump) pressures. Figures 4.3.2.3 and 4.3.2.4 are Main Engine #1 pitch actuator temperatures at 5 hours after the start of cryo fill for low and high pressure operation, respectively.

FIGURE 4.3.2.1

MPT - SF2 - 5/19/78 - LOW PRESS FLOW (300PSI)
~ 5 HRS TANKING ~
MPTA SCHEMATICS



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MPTA SCHEMATICS

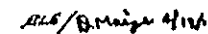
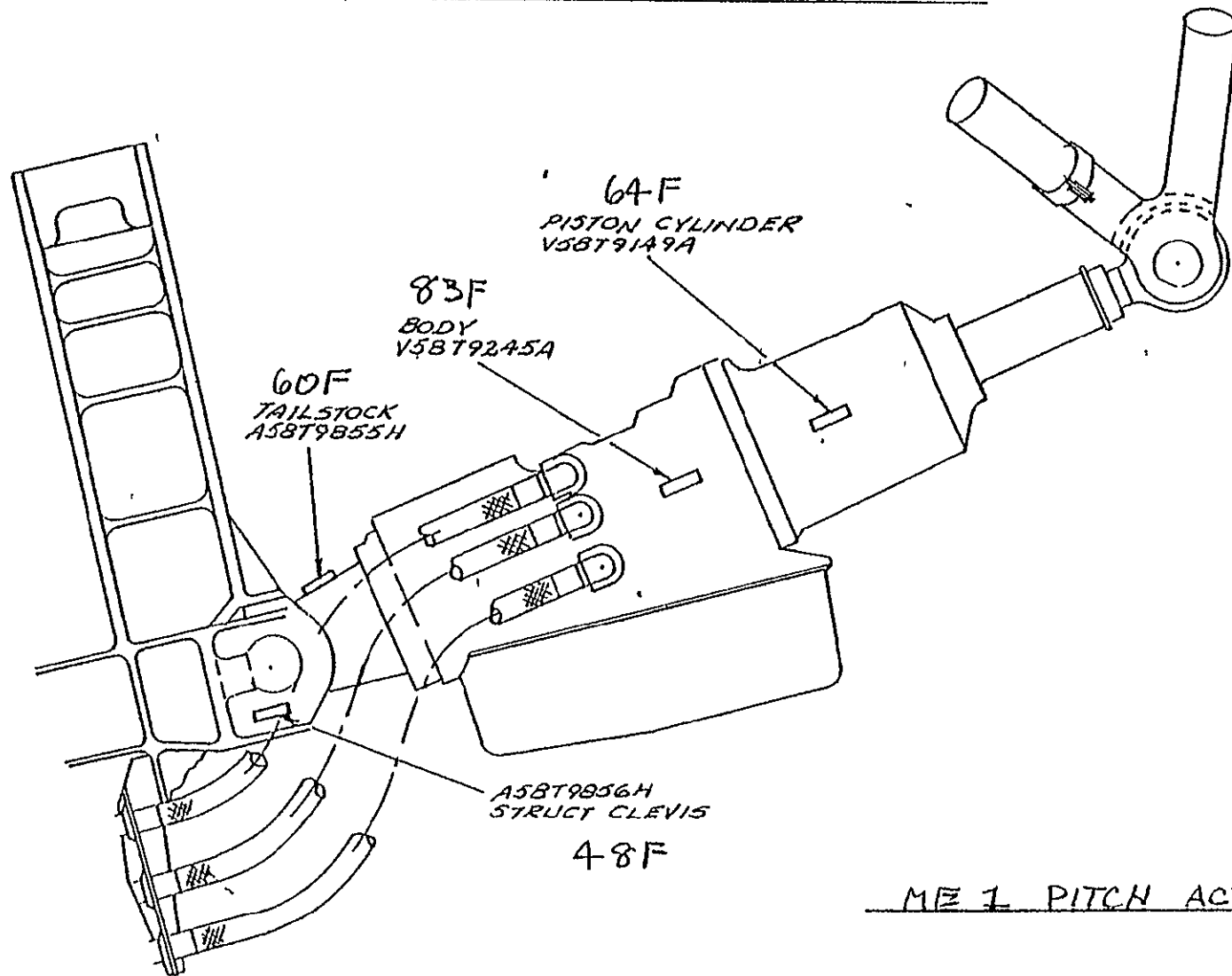


FIGURE 1.3.2.3

MPT - SF2 - 5/19/78 - LOW PRESS FLOW (300 PSI)

~ 5 HRS TANKING

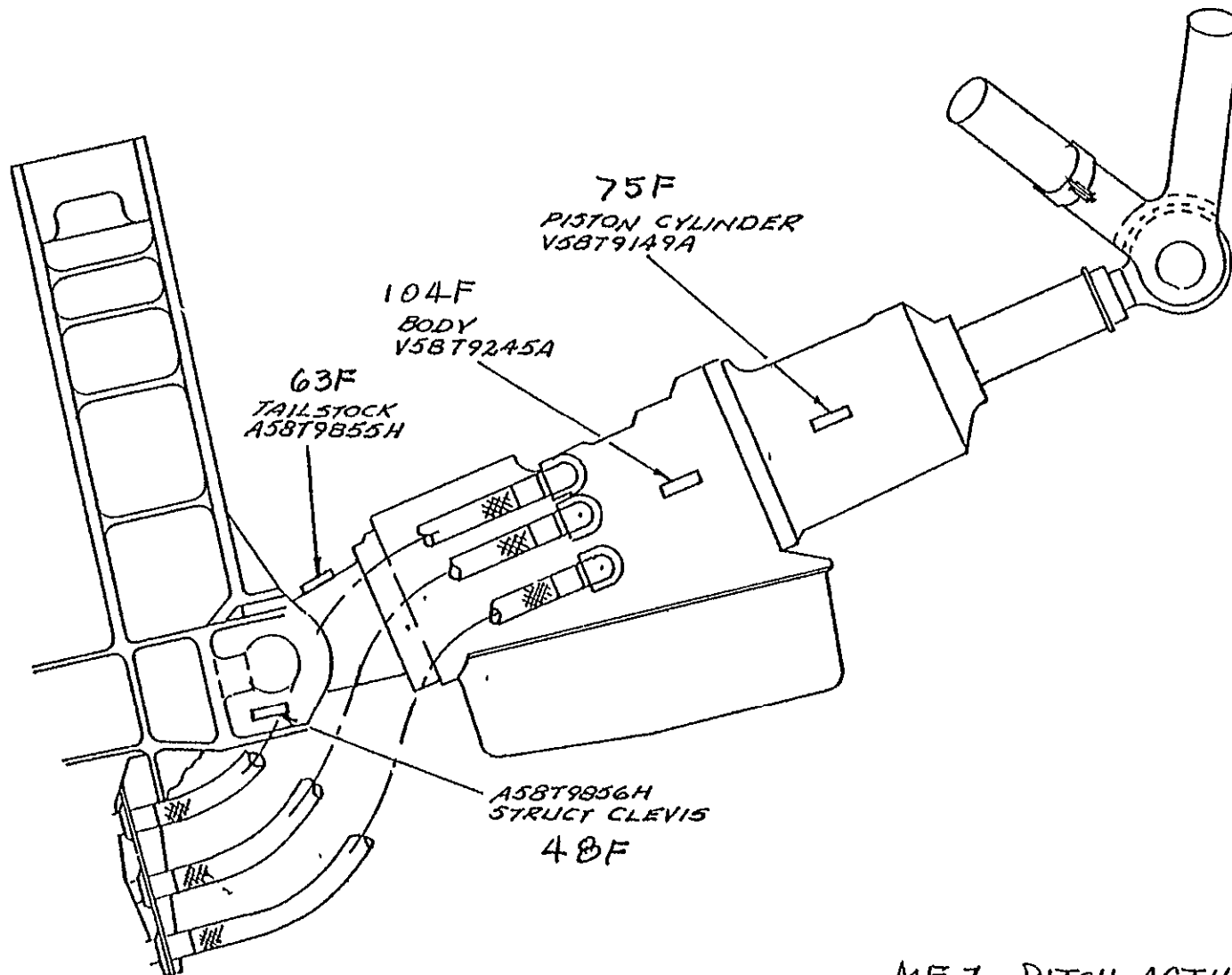


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ME 1 PITCH ACTUATOR

FIGURE 5.2.4

MPT - SEZ - 5/19/78 - HIGH PRESS FLOW (3000 PSI)



MEI PITCH ACTUATOR



4.4 Purge and Vent Analysis

4.4.1 Orbiter Purge System

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4.4.1.1 Aft Fuselage Compartment Purge

The design objectives of the purge system are to 1) maintain a positive pressure in the aft fuselage (AF) to prevent air intrusion, 2) prevent accumulation of hazardous gases, and 3) maintain the temperature of the main engine controllers and compartment structure within allowable limits.

Set-up: The purge system flow rates for the test were as follows:

| | |
|---------------------|--------------|
| Mid Fuselage Plenum | 159.9 lb/min |
| Aft Fuselage | 65.3 lb/min |

The aft fuselage compartment vent doors were set in the purge position for the test.

Test Results: The pressure in the aft fuselage compartment varied between 0.04 to 0.10 psig during the test. A minimum pressure of 0.019 psig is required to prevent air intrusion with a 30 knot wind.

The purge system prevents the accumulation of hazardous gases. The inerting of the aft fuselage from air (20.95% O₂ and 0.95% Argon) to less than 50 parts per million of O₂ was achieved in approximately 15 minutes as indicated on the hazardous gas detection system (HGDS) mass spectrometer. The temperature of the structure and the bulk gas were both well above the lower limit of minus 50F. For additional details on temperatures, see Section 4.6.1.

The aft fuselage compartment purge system met or exceeded all the design requirements for the static firing test.

4.4.1.2 ET/Orbiter Disconnect Purge

The purpose of this purge is to maintain a positive pressure in the ET/Orb disconnect plate gap to prevent cryo-pumping on the LH₂ side and to prevent ice build-up on the LOX side.

A redline value of 0.08 psig minimum was established for the LH₂ side. The minimum pressure recorded during the test was 0.11 psig. The pressure is recorded on two strip chart recorders with a measurement range of 0-0.25 psig.

The ET/Orbiter disconnect purge system exceeded all design requirements during the static firing test.



4.4.2 PURGE AND VENT - ET

The updated thermal math model of the Intertank for a 75 to 85°F ambient day predicts an Intertank gas temperature of $-181^{\circ}\text{F} \pm 15^{\circ}\text{F}$. The four DTI Intertank gas temperatures read within 5°F of the nominal predicted value (i.e., between -176 and -186°F) when the Intertank gas temperature reached steady state.

The DFI box gas temperature thermal math model predicts a gas temperature of $+3^{\circ}\text{F} \pm 5^{\circ}\text{F}$ for the ambient conditions on the test day. The DFI compartment gas temperature measurements were reading +3 and $+5^{\circ}\text{F}$ in the DFI box when it reached steady state.

The Intertank hazardous gases were purged as predicted.



4.4.3 Hazardous Gas Detection System (HGDS) (U72-1186)

The design objective of the HGDS is to detect the presence of hydrogen, oxygen, argon and helium in the aft fuselage and the ET/Intertank compartment.

Prior to inerting the aft fuselage with GN_2 , oxygen and argon were detected. Approximately 15 minutes after initiation of the GN_2 inerting purge, the oxygen content was reduced from 20.95% to 50 parts per million. Hydrogen was detected just subsequent to firing. The peak value was 600 parts per million (ppm) decreasing to less than 100 ppm in two minutes and remained at or below this level for the remainder of the test.

A helium reading of 0.8% helium in the aft fuselage was detected. This leakage may have occurred in the ET/Orbiter disconnect circuit and/or from the MPS components.

Calibration tests (H_2 , O_2 , Helium, Argon) before and after the static firing test. shows no degradation of performance of the HGDS.

The HGDS performed satisfactorily during the static firing test.

4.4.3.1 Delta Hazardous Gas Detection System (HGDS-C70-1179)

The design objective is to detect hydrogen in selected locations in the aft fuselage, ET/Intertank, helium purge outflow line from the LH_2 T-O umbilical panel and facility.

At approximately T-70 minutes, the sensor above main engine number one gave an indication of hydrogen. The value increased slowly to approximately 0.1% at T-105 seconds. The values are estimated since the reading is below the lower calibration limit of 0.5% hydrogen. At T-105 seconds the reading increased to between 0.2 to 0.3%. At T+10 minutes the level had decreased to zero.

At approximately 1543 hours during the detanking, the sensor above main engine number one detected hydrogen which increased to approximately 0.3% over a period of approximately 15 minutes. At the same time sensor number 5 (prevalve cluster area) indicated less than 0.1% hydrogen. The 5000 SCFM purge was activated and the hydrogen concentration decreased to zero in 8 minutes. The 5000 SCFM purge was secured at this time and there were no further hydrogen indications.

The delta hazardous gas detection system performed satisfactorily during the static firing test.



4.5 Structures

4.5.1 Structural Analysis - Orbiter

4.5.1.1 Loads

There were no indicated structural loads problems on SF-2. PCM strain gage data for ET/Orbiter attachment loads agree well with predicted loads. All of the hardwire measurements for ET attachment loads have been squawked.

There are no structural loads problems anticipated for thrust build-up to 90% of rated thrust. Predicted loads for 90% thrust (with no winds) are about one-half of design loads.

Ignition Overpressure

Three ignition overpressure transducers were installed in the "Orbiter" base heat shield and seven in the MPTA test stand for SF-2, as for SF-1. All measurements, except F48P9977H, displayed output. However, following review of the output, all of the measurements were "squawked." The squawks requested a verification of measurement system integrity and calibration. No data, considered valid, on ignition overpressure has been obtained from SF-1 or SF-2.



4.5.1.2 Stress

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The stress analysis results of the 19 May, 1978 firing (SF-2) are contained in this section.

4.5.1.2.1 Aft Fuselage Structure - Vibroacoustic Response

Monitored instrumentation revealed the dynamic responses were as expected, similar to SF-1, for this 70% power level firing. Power Spectral Density (PSD) plots and Root Mean Square (RMS) strain data have been requested for future detail evaluation.

One vibroacoustic gage was noted to be either defective or incorrectly calibrated. In addition a 16.5 Hertz signal of unknown origin was noted in the oscillograph data. This signal was present before, during and after the test engine firing. Data squawks have been submitted to rectify these problems.

4.5.1.2.2 Shell Structure Strain Gages

Nearly all monitored strain gages revealed negligible response data, stresses less than 6000 psi, for this 70% power level test. The 3569800H strain gage at the X₀ 1307 wing strap indicated a tensile stress of 12,000 psi as was anticipated.

An unexplained 16.5 Hertz signal appeared throughout all data and one strain gage is either defective or calibrated incorrectly. Data squawks have been submitted to remedy these problems.

4.5.1.2.3 Frames and Bulkhead Strain Gages

All monitored strain gages were well within acceptable limits. The maximum stress recorded in titanium structure was approximately 26,000 psi. The maximum stress recorded in aluminum structure was approximately 10,000 psi.

A 16.5 Hertz signal of unknown origin appeared throughout a good deal of the data and one gage did not record any strain where significant strain was anticipated. Data squawks have been submitted to remedy these problems.

4.5.1.2.4 Primary Thrust Structure Strain Gages

Twenty-one (21) strain gages mounted to the primary thrust structure were monitored. PSD's and RMS strain data have been requested for future analysis of dynamic strain contributions in the thrust structure. A summary of anticipated member strains, derived from MPLA proof test



influence coefficient data, versus corrected SF-2 actual member strains is contained in Table 4.5.1.2-1. From this summary of results it can be seen that four strain gages exceeded anticipated levels to an appreciable extent ($> 30\%$ exceedance). Three of these gages are relatively lightly loaded. One strain gage A35G9908H on the V070-351121 aft thrust truss strut is comparatively highly loaded but this strut is capable of surviving an ultimate strain of approximately three times the level experience on SF-2. It was also noted that the back to back strain gages located on the aft portion of the V070-351108 main lower thrust structure strut read much lower than expected. Investigation is currently in progress to attempt to explain this phenomenon.

Nearly all strain gage oscillograph data contained a 16.5 Hertz signal of unknown origin throughout the data, before, during and after engine firing. This signal was of sufficient amplitude such that in many instances it was as large as the primary load displacement. In addition to the 16.5 Hz anomaly one gage was either defective or calibrated incorrectly. Squawks on all apparent malfunctions have been submitted for rectification prior to the next firing.

4.5.1.2.5 Manifold Support Strut Strain Gages

Four (4) strain gages mounted to the LO_2 and LH_2 manifold support struts were monitored. One strain gage yielded totally useless erratic data. The other three gages contained a 16.5 Hertz signal whose amplitude exceeded the anticipated strains in the supports. Data squawks were submitted to rectify these anomalies. The response to the LO_3 source pressure after shut-down which occurred during SF-1 on the manifold supports could not be detected in the SF-2 data due to the magnitude of the 16.5 Hz extraneous signal.

Table 4.5.1.2-1

Summary of Thrust Structure Strains

| Strain
Gage
Number | Location
Part/No. | Recorded
Strain | 16.5 Hz
Error | Corrected
Strain | Predicted
Strain | Ratio
Actual/
Predicted | Capability
(Min.) |
|--------------------------|----------------------|--------------------|------------------|---------------------|---------------------|-------------------------------|----------------------|
| | | ① | ② | | ③ | | ④ |
| A35G 9901H | V070-351124 | 720 | -60 | 660 | 681 | .97 | 3801 |
| 9908 | 1121 | -1140 | 0 | -1140 | -880 | 1.30 | 3385 |
| 9910 | 1149 | 780 | 0 | 780 | 705 | 1.11 | 4315 |
| 9912 | 1263 | 1080 | -120 | 960 | 955 | 1.01 | 4013 |
| 9914 | 1120 | 400 | -300 | 100 | 123 | .81 | 2285 |
| 9917 | 1139 | -360 | +30 | -330 | -317 | .84 | -2036 |
| 9918 | 1139 | -360 | +120 | -240 | -395 | .61 | -2036 |
| 9919 | 1806 | -1050 | +150 | -900 | -886 | 1.02 | -4455 |
| 9920 | 1806 | -1200 | +150 | -1050 | -1051 | 1.00 | -4455 |
| 9931 | 1108 | -1500 | +300 | -1200 | -1080 | 1.11 | 4653 |
| 9932 | 1108 | -1680 | +180 | -1500 | -1525 | .98 | 4653 |
| 9933 | 1108 | -900 | +180 | -720 | -999 | .72 | 4653 |
| 9934 | 1108 | -720 | +150 | -570 | -1232 | .46 | 4653 |
| 9945 | 1212 | 300 | -120 | 180 | 205 | .88 | 2548 |
| 9947 | 1211 | 0 | - | 0 | -159 | - | 1911 |
| 9949 | 1210 | 300 | -195 | 105 | 239 | .44 | -2401 |
| 9951 | 1825 | 600 | -360 | 240 | 229 | 1.05 | -1875 |
| 9953 | 1825 | 900 | -450 | 450 | 333 | 1.35 | 6585 |
| 9961 | 1958 | -600 | +480 | -120 | -66 | 1.82 | 2740 |
| 9963 | 1126 | -600 | +360 | -240 | -94 | 2.55 | 4003 |
| 9969 | 1209 | -375 | +195 | -180 | -184 | .98 | -1203 |

①

SF-2 Raw O'graph Data.

②

Correction for 16.5 Hz extraneous signal in data.

③

Prediction based on MPTA influence coefficient tests.

④

Ultimate strain at the design load condition.

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4.5.1.3 Vibroacoustics

Thirty-one (31) vibration and five (5) acoustic measurements from the MML and 36 vibration, 42 strain, and 12 acoustic measurements from TR-SI32004 were monitored during SF-1. Seven (7) MML vibration (A08D9433, A08D9434, A08D9436, A08D9589, A08D9649, and A08D9560) and all five (5) MML acoustic (V08Y9681, V08Y9684, V08Y9686, V08Y9689, and V08Y9692), did not function correctly during the firing. TR-SI32004 vibration measurement 2126, and strain measurements 3048HL, 3021, 3236, and 3237 did not function correctly.

Acceleration spectral density analysis (ASD's) of the MML functional vibration measurements show the levels, when scaled upward to a 109% thrust level, to be within the existing random vibration criteria for the measurement's locations. Operational MML acoustic measurements will be required before exact 109% thrust vibration levels can be established. Evaluation of the TR-SI32004 vibration ASD's is currently in progress.

The 24 Rocketdyne Division strain gages on the low pressure turbo pump flange showed a maximum of approximately 30 In/In RMS based on Space Division strain spectral analyses of the measurements. Telecons with Rocketdyne personnel have established that their analyses of the data has produced the same results.

Evaluation of the TR-SI32004 acoustic measurements in conjunction with MML overpressure measurements is still in progress at this time.



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4.5.2 STRUCTURES - EXTERNAL TANK

4.5.2.1 Loads

An analysis of the thrust strut instrumentation revealed that the average thrust per engine was 295,000 pounds. This is approximately 73% of full engine thrust.

4.5.2.2 Stress

An investigation of all strain gages on the tank showed that the highest stress was 16,300 psi, and this occurred in the forward left Orbiter attach fitting. This stress was determined from the difference between the strain before and during engine firing. It does not account for the relieving stress due to the weight of the Orbiter (acting opposite to the thrust stress). However, even without the Orbiter weight stress being subtracted, the stress level is well below the allowable level of 52000 psi.

4.5.2.3 Vibroacoustics

Review of O-gram data for the MPTA 2nd firing was accomplished with the following conclusions:

| | | |
|----------------|------------------|------------------|
| Low Frequency | 22 good channels | 13* bad channels |
| High Frequency | 29 good channels | 3* bad channels |
| Acoustic | 7 good channels | 0* bad channels |

*Data squaks were implemented for all bad channels

The PSD data requested, after review of the O-grams, has not been received from the computer facilities.. This data is required to make any valid assessment of the vibroacoustic environments.



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4.5.3 POGO

There were no POGO objectives planned for static firing test number two (SF2-001) that was conducted on 19 May, 1978. However, a review of the SF2-001 data is being performed for assessment of system responses, for correlation with analytical predictions, and for evaluation of data quality.

A preliminary evaluation of feedline pressure data indicates that the frequency of the fundamental feedline mode is in good agreement with analytical predictions. The LPOTP inlet pressure responses to engine start transients were approximately 40 psi peak to peak, and they decayed as expected in 4 to 6 seconds. These LPOTP inlet pressure responses during steady-state burn were equal to or less than 7 psi peak to peak at 3 Hz. Their responses to engine shutdown transients were approximately 50 psi peak to peak. The dynamic signature throughout the rest of the LOX feedline system was similar to the LPOTP inlet pressure. The first feedline mode appears to be approximately 3 Hz which corresponds to analytical predictions.

POGO Analysis predicts significant coupling at 3 Hz between structure, feed system, and engine system. There was no evidence in SF2-001 data for divergent oscillation at 3 Hz, nor at the higher frequencies.

Using Rocketdyne engine gains, a worst case analysis shows the system to be stable for the SF3-001 15 second firing at 90% power level. The analysis for extending the burn time to 40 seconds will be completed by 2 June, 1978. It is recommended that plans proceed for SF3-001 without a POGO suppressor. Thirty-four (34) individual squawk-sheets were prepared on SF2-001 POGO instrumentation and/or data anomalies.

This number is compared with 56 squawk sheets prepared for SFI-002. The SF2-001 squawks include dead signals, bias shifts, erratic signals, clipped signals, and signals without NSTL station calibrations. Corrective action



4.5.3 POGO (Continued)

should be taken for all of these anomalies prior to SF3-001.

The data from the nine (9) accelerometers in the POGO Safety Cutoff System were judged to be unusable. These were three gimbal, three HPOTP, and three LPOTP accelerometers. The source of the anomalies noted on the data is currently being investigated. This includes the checking of coaxial connectors, moisture, proper torque, open shields, and full-scale range settings. A Special Action Requirement (SAR) N-410 has been written to perform an end-to-end insertion check on this instrumentation prior to SF 3-001. The cutoff system should be monitored during SF 3-001, but NOT enabled.



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4.6.1 Thermal Analysis

SUMMARY

Temperature data for the tanking and autosequence phases of MPT SF2-01 have been reviewed and did not indicate any problems with respect to the Thermal Control System for MPTA or OV 102. All of the bulk GN₂ temperatures were well above the minimum limits established for thermal design during the test and cold bulk GN₂ stratification was minimal. Similarly, all of the structure measurements were well above minimum limits.

A preliminary evaluation of these results indicates that apparently the MPS cryogenic heat gain is below the levels used for OV 102 design. At this point in time, however, analysis has not been performed to establish environmental heat gain differences between OV 102 and MPTA. Future MPTA tests, however, should continue to exhibit compartment bulk GN₂ and structure temperatures well within the levels previously established for OV 102 prelaunch design.

Test Configuration & Conditions

MPTA considerations which would affect the compartment temperature responses in comparison to OV 102 were as follows.

1. The PV&D GN₂ purge flow rates and inlet temperatures for MPT SF2-01 are given in Table 4.6.1-1. As shown, the Circuit #3 flow rate is essentially the same as used for OV 102 compartment thermal control design. The flow rate for Circuit #2 (1307 plenum) was considerably higher than the design value. Inlet temperatures were somewhat higher during the test than the design value.
2. Major structural/insulation differences between MPTA and OV 102 include: a) an aluminum boilerplate base heat shield on MPTA, b) uninsulated OMS decks on MPTA.
3. Ambient air temperatures ranged from 74°F to 87°F during MPTSF2-01 tanking/autosequence.

DISCUSSION

A brief summary of MPTSF2-01 minimum temperatures during tanking/autosequence is given in Table 4.6.1-2.

A review of the data shows all of the measurements were within expected limits during both tests. The primary concern relative to tanking was the capability of the PV&D GN₂ purge system to maintain temperatures above the limits established for OV 102. For OV 102, MPS cryogenic components are expected to absorb approximately 50 Btu/sec from the aft fuselage compartment during cryo loading and prelaunch hold. The PV&D GN₂ temperature available, however, indicates that the actual MPS cryo heat gain is probably somewhat lower. Based on the PV&D GN₂ flow rates, inlet temperatures and exit temperatures, data from MPTSF2-01 indicated energy loss from the GN₂ at

Table 4 6 1-1 PV&D GN₂ Inlet Temperature/Flow Rate During
Tanking

| | Circuit #2
(1307 Plenum) | Circuit #3 |
|---|--------------------------------|--------------------------------|
| . MPTSF2-01 | 159.9#/Min @ 72 ⁰ F | 65.3#/Min, @ 75 ⁰ F |
| OV 102 (Min Guaranteed/Non Cryo
Payload) | 118#/Min @ 70 ⁰ F | 66.8#/Min @ 70 ⁰ F |
| . OV 102 (Min Guaranteed/Cryo
Payload) | 135#/Min @ 40 ⁰ F | 66.8#/Min @ 70 ⁰ F |

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Table 4.6.1-2 Aft Fuselage Compartment Temperature Summary

| | OV 102 Prelaunch
Min Design Limit | MPTSF2-01 Min
Temperatures
Recorded |
|---|--------------------------------------|---|
| Compartment Bulk GN ₂ Temperatures | -50 ⁰ F | +8 to +60 ⁰ F |
| Fuselage Structure | -- | +23 to +68 ⁰ F |
| Thrust Structure Boron Epoxy | -80 ⁰ F | +30 to +62 ⁰ F |
| SSME Gimbal Bearings | -50 ⁰ F | +42 ⁰ F |

DISCUSSION (Continued)

29 Btu/sec. Considerable uncertainty is associated with knowing the true aft compartment inlet temperature for the 1307 plenum flow as well as measurement tolerances. The MPS cryo heat gain could be approximated as equal to the GN₂ energy loss plus environmental heat gains and subsystem heat losses. At this time, environmental heat gains and subsystem heat losses have not been established.

Although PV&D GN₂ purge flow rates and/or temperatures were high with respect to OV 102 design, an evaluation of the data does not indicate that any major problems regarding minimum temperatures will be encountered in future MPTA tests. Similarly, no major problems are expected for the Thermal Control System on OV 102.

4.6.2 THERMODYNAMICS - ET

The Intertank structural temperatures were calculated to be $-155^{\circ}\text{F} \pm 30^{\circ}\text{F}$. Data from five DFI sensors showed steady state I/T skin temperatures between -150 and -160°F with one failure. Two of the DTI sensors yielded continuous data reaching steady state temperatures of -128°F and -173°F . Data from a third DTI measurement steadied out at -122°F after an erratic beginning.

The Intertank Y-joint skin temperature in the area where temperature sensors are located were calculated to be $-200 \pm 50^{\circ}\text{F}$. Data from this area show steady state readings of -198°F , 213°F , and -229°F at Stations XT1110, XT1112, and XT1114, respectively. LO₂ and LH₂ structure temperature decreased predictably as the propellants were loaded. The TPS surface temperatures after propellant loading were below ambient and above freezing as expected. Erratic TPS surface temperatures were recorded in areas affected by solar fluxes.

Ice/Frost was not an objective of this test.



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4.7 Ground Support Equipment

4.7.1 Orbiter Provided

4.7.1.1 Mechanical

H77-0741 Aft ET Support Struts Temperature Control -
No anomalies encountered. System performed as anticipated.
The strut temperature recording during firing and for approximately
6 1/4 hours preceeding firing show a minimum of 72° F. This
temperature is substantially above the minimum required temperature
of 25° F.

S70-0756 Hydraulic Distribution and Simulation Unit -
No anomalies were encountered during the operation.

4.7.1.2 Fluid

S72-0618. NSTL Fluid Distribution System

The operation of the Rockwell provided fluid systems was
satisfactory. Observed anomalies did not effect the test results.
Reverse flow occurred in the LH₂ High Point Bleed System, when
facility valve TCV106 introduced LH₂ into a common facility line
used to route the high point bleed flow to the 18-inch GH₂ vent line.
A facility modification is planned to incorporate a separate 3-inch
line for the high point bleed.

The Pogo Pulser was installed, but not operated during the static
firing. The GN₂ cavity purge was on during the test, and the
cavity purge and hydraulic seal drain redline pressure transducers
were monitored without any anomalies. The return line turbine
flowmeter (Measurement No. G58R8766H) showed an oscillating signal
from around 30 to 60-GPM at 2 to 3-Hz during the firing. This
could be caused by movement of the piston within the pulser.

An Auxiliary LO₂ Helium Injection System was installed and used for
SF2.

Additional insulation is being added to all fluid lines in the
vicinity of the T-O umbilicals in order to support a static firing
with a duration exceeding 15-seconds. The use of reflective tape
proved to be adequate for firing up to 15-seconds.



S72-0741, MPTA Purge and Pressurization Console

One leaking regulator was discovered during setup, and replaced prior to the test.

Test data indicated that the pre valve actuation regulator (Console B) was set approximately 25-PSIG above the 800-PSIG maximum value.

S72-1005, Pneumatic Servicing Console

All systems performed in a satisfactory manner during the test. A redundant pressure regulator in the SSME Purge System leaked during setup, and was isolated during the test. Subsequent to the last static firing (SF1), the LO₂ and LH₂ prepressurization valve timing was changed to decrease the closing time. The closing port orifices for the LO₂ valves were removed, and the LH₂ valve orifices were increased from 0.025-inch diameter to 0.035-inch diameter. The faster closing time has eliminated the ullage pressure overshoot problem.

4.7.1.3 Electrical GSE

The Electrical GSE provided under the Orbiter contract performed satisfactorily during Static Firing Test SF-2. None of the SATS anomalies that had occurred during the previous static firing countdowns were observed. The improved operation is the result of SATS hardware problems isolated and corrected prior to SF-2 and of software modifications incorporated during the same period.



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4.8 THERMAL PROTECTION SYSTEM - ET

Ten LH₂ and eight LO₂ pressure cycles have been conducted thru SF2 with minimal damage to the TPS. SF2 produced no new divots or cracks except for negligible damage to the surfaces of the LOX antigeysers and feed lines. This damage is believed to be due to cold gas impingement from the intertank fairings and physical contact between the LOX fairing seal and the orbiter side of the LOX feedline. Current MPTA TPS repair guidelines do not necessitate repair of these items beyond a topcoat touchup.

There are no anticipated TPS constraints to conducting SF3 as planned.